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Economic Alternatives to Tepee Burners for the Disposal of Wood Residue in Montana

Geomet, Inc.
Gaithersburg, MD

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May 1980

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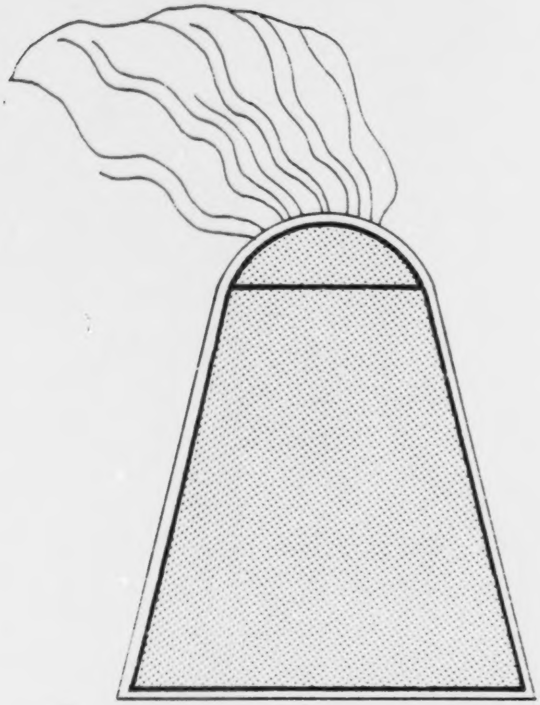

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During the spring of 1980, there were still over 30 tepee burners operating within the State of Montana. Though these burners are useful to sawmills still employing them, the burners are expensive to operate, consistently violate Montana's air quality rules, and are an extremely wasteful method for disposing of an increasingly valuable natural resource.

This study was conducted to determine the problems facing mills employing tepee burners that might prevent them from shifting away from the burning of wood residues towards marketing them, and to determine steps that the State of Montana and/or the U. S. Government might take to encourage that shift without levying an undue hardship on these mills or the forest products industry.

The major problem facing tepee burner mills, particularly smaller ones, is financing the capital equipment necessary to make wood residue marketable. A secondary problem is transporting the wood residue to markets.

Several existing methods for solving the first problem exist. The U. S. Small Business Administration (SBA) offers low interest loans in two of its programs that can assist small mills to make the necessary capital expenditures at feasible return rates. Furthermore, it might be possible for the State of Montana to initiate a low interest loan program tailored to the small sawmill's needs, using revenues from the Coal Severance Tax.

If additional startup assistance appears necessary, the State might also consider a short term tax rebate program aimed at sawmills that phase out their burners and begin selling their wood residues, or an accelerated depreciation schedule for mills purchasing the necessary capital equipment, or combinations thereof. These incentive programs, together with the rising demand for wood residue in Montana, indicate that it should be possible to phase out the tepee burners in a way that eliminates the air pollution problem while improving the economic position of mills now using them.

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SECTION 1.0

EXECUTIVE SUMMARY

During the spring of 1980, there were still over 30 tepee burners operating within the State of Montana. These burners are used by sawmills to dispose of some or all of the wood residue produced during normal operations. Though these burners are useful to sawmills still employing them, the burners present two problems. First, they are expensive to operate and consistently violate Montana's air quality rules, a defect that cannot be remedied by equipment modification or improved operation or maintenance. Second, burning wood residue is an extremely wasteful method for disposing of an increasingly valuable natural resource, one steadily increasing in demand for fuel and other purposes.

This study was conducted to determine the problems facing mills employing tepee burners that might prevent them from shifting away from the burning of wood residues towards marketing them, and to determine steps that the State of Montana and/or the U.S. Government might take to encourage this shift without levying an undue hardship on these mills or the forest products industry.

The demand for wood residues in Montana and elsewhere is expected to increase steadily in the immediate future, particularly if the expected recession in the U.S. is not severe. One pulp plant now being expanded in the Missoula area alone is expected to purchase as much as 90 percent of the wood residue produced in the State beginning in the fall of 1980. Other markets for wood residue may expand as well. This means the chances of marketing residue from a wood-burning sawmill are good, provided that certain practical problems can be solved.

The major problem facing tepee burner mills, particularly smaller ones, is financing the capital equipment necessary to make wood residue marketable. In a typical mill, this means the purchase and installation of equipment for grinding residue into a form suitable for sale as boiler fuel, and the storage facilities necessary for convenient and economical truck pickup for transport to markets. This capital investment is not enormous, ranging from $50,000 to $150,000 depending on the size of the mill, the type of equipment purchased, the installation problems to be solved and related considerations. But such an outlay could be prohibitively expensive at today's bank lending rates, particularly for sawmills that are operating on comparatively thin financial margins.

A secondary problem is transporting the wood residue to markets. In Montana, truck and rail transport are the only significant modes available.

Truck transport at current hog fuel prices is expected to be economically feasible for mills situated within 100 miles of a major buyer of wood residue. Mills located further away from buyers may have to rely on a combination of truck and rail transport, an arrangement that complicates the cost picture, but one that may still prove economically feasible if both buyer and seller share in the increased transportation costs.

Several existing methods for solving the first problem exist. The U.S. Small Business Administration (SBA) offers low interest loans in two of its programs that can assist small mills to make the necessary capital expenditures at feasible return rates. Furthermore, it might be possible for the State of Montana to initiate a low interest loan program tailored to the small sawmill's needs, using revenues from the Coal Severance Tax.

If additional startup assistance appears necessary, the State might also consider a short term tax rebate program aimed at sawmills that phase out their burners and begin selling their wood residues, or an accelerated depreciation schedule for mills purchasing the necessary capital equipment, or combinations thereof. These incentive programs, together with the rising demand for wood residue in Montana, indicate that it should be possible to phase out the tepee burners in a way that eliminates the air pollution problem while improving the economic position of mills now using them.

This report was submitted in fulfillment of Contract Number 68-01-4144, Task 6, by GEOMET, Incorporated under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period November 1, 1979 to May 15, 1980, and work was completed as of May 15, 1980.

SECTION 2.0

THE AIR POLLUTION ASSOCIATED WITH TEPEE BURNERS IN MONTANA

During the past 10 years, the Air Quality Bureau has received more complaints about the emissions from tepee burners than from any other source. The complaints have concerned both wood smoke and settled particulate. A typical tepee burner is shown in Figure 2.1.

During 1979, the Air Quality Bureau inspected all tepee burners operating at Montana lumber mills and found over 70 percent to be in violation of the State's air quality rules. The tepee burners were typically found to exceed opacity limitations, to be poorly maintained, and to be operated under poor incineration conditions.

Wood smoke from tepee burners can cause air quality problems for miles downwind. In mountain valleys, where most tepee burners are located, the smoke can build up to excessive levels, especially during inversion periods. Most mountain valleys frequently have inversions in the early morning hours, during the same time period that tepee burners are starting up and emitting large amounts of smoke. Even a tepee burner that is operating completely in compliance with the Montana air quality rules can cause smoke problems for the residents of the area. The causes of smoke emissions are discussed in section 2.1; section 2.2 describes the difficulties to be overcome in running a clean-burning tepee burner.

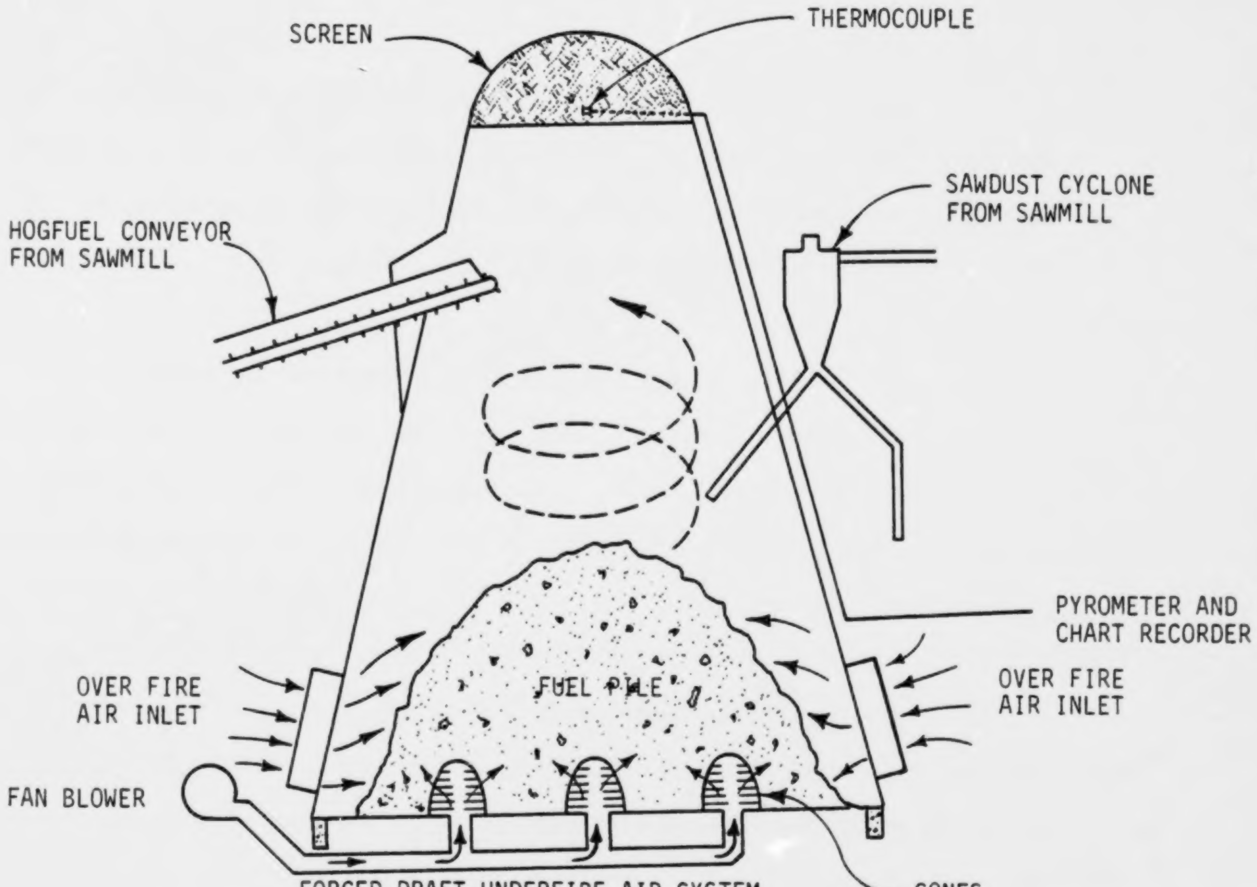
SCREEN
THERMOCOUPLE
SAWDUST CYCLONE FROM SAWMILL
HOGFUEL CONVEYOR FROM SAWMILL
PYROMETER AND CHART RECORDER
OVER FIRE AIR INLET
FUEL PILE
OVER FIRE AIR INLET
FAN BLOWER
FORCED DRAFT UNDERFIRE AIR SYSTEM
CONES

Figure 2-1. Typical Tepee Burner

Settled particulate from tepee burners consists of small pieces of partially burned wood residue ranging up to 0.25 inch in diameter. These small particulates generally fall out of the air within 1 mile of the source, causing an unsightly mess when they land on cars, patios, window sills, sidewalks, and so forth. The associated carbon is almost impossible to clean off when it comes in contact with car seats, carpets, or clothing. In general, settled particulates from tepee burners can be a severe nuisance and result in property damage for those persons living immediately downwind. The causes of settled particulate emissions are discussed in sections 2.1 and 2.2.

Tepee burner emissions also represent a fire hazard; burning particulates emitted from tepee burners have been responsible for numerous fires both on and off sawmill property. At night, glowing embers from the burners can be observed traveling hundreds of yards downwind.

2.1 Operational Problems of Tepee Burners

The major factor in operating a tepee burner with minimum smoke and particulate emissions is maintaining the exit gas temperature between 600 and 900°F. At temperatures below this range, the tepee burner will not be hot enough to allow complete combustion, thus it will emit smoke. At temperatures above this range, the resultant excessive exit gas velocities will pull small pieces of wood residue out of the tepee burner before they are completely burned, causing particulates to settle. At temperatures above 900°F, the burner's structural members, shell plates, screens, and temperature-sensing devices can be damaged.

For a tepee burner to reach and maintain an efficient operating temperature, it must be properly sized to the amount of fuel it has to burn. Most tepee burners in Montana were designed and constructed before the mills were able to sell any wood residue. However, most mills currently sell chips and, in some cases, shavings and sawdust; consequently, their burners are oversized. It is very difficult to maintain an efficient operating temperature in an oversized tepee burner.

The type of wood that a sawmill is cutting can definitely affect a tepee burner's operation. Some woods, such as fir and larch, burn very well, whereas others, such as spruce, are very difficult to burn. Some sawmills cannot burn spruce without creating excessive amounts of smoke.

The weather can have a dramatic effect on the operation of a tepee burner. During the warmer months, rain can cool the shell, causing the exit gas temperature to drop and the tepee burner to smoke. During the winter, the ambient temperature makes it much more difficult to bring the tepee burner up to an efficient operating temperature. During extremely cold weather, it is almost impossible for a burner to operate without smoking. Snow and ice attached to the log bark generally end up in the tepee burner, which retards the fire and lowers the exit gas temperature. High winds can cool the burner shell and cause smoke; wind can also pull partially burned material out of the tepee burner, causing settled particulate problems.

During the morning startup period, tepee burners emit large amounts of smoke until the exit gas temperature reaches 600 to 900°F. For some tepee burners, the startup period lasts approximately 1 hour. However, for most tepee burners, the startup period requires 2 hours or more. The Montana air quality rule regulating tepee burners exempts smoke emissions for the 1st hour of operation. However, during the 1st hour, a tepee burner can emit enough smoke to cause significant air quality problems.

One of the most important aspects of maintaining an efficient exit gas temperature is to maintain a steady flow of fuel into the tepee burner. However, during coffee breaks, lunch hour, shift change, and breakdowns in the mill (which occur frequently), the flow of fuel is stopped or severely retarded. This can cause the fire to die down, the exit gas temperature to drop, and the tepee burner to smoke.

Some sawmills that operate two shifts per day operate only part of the mill during the second shift; during the second shift, less fuel is sent to the tepee burner, making it difficult to maintain an efficient exit gas temperature.

At night and on weekends, the wood residue left in the tepee burner usually smolders until it goes out. Often the small smoldering fuel pile creates large amounts of smoke; it is virtually impossible to keep the exit gas temperature at an efficient level until all the fuel is consumed.

The type of wood residue fed into a tepee burner makes a significant difference in operation. Slabs, chips, and shavings burn very well, whereas sawdust and bark are much more difficult to burn. Many sawmills currently chip all their slabs and then sell the chips and shavings. This leaves only the bark and sawdust, the most difficult types of residue to burn in a tepee burner. Most sawmills now use the more efficient narrow-kerfed saws. To avoid overheating, the thin saw blades are continually sprayed with water. Unfortunately, this creates a wet sawdust that is very difficult to burn.

Some sawmills use their tepee burners to dispose of mill yard cleanup materials. Usually this material, which is cleaned off the ground with a front-end loader, often contains dirt and rocks that retard the fire and plug the grates. Sometimes the cleanup material also includes items such as used oil filters and tires, which cause smoke problems.

To operate a tepee burner correctly, the sawmill manager must designate a person on each shift as burner operator. The burner operator must monitor the tepee burner's emissions and exit gas temperature and make any necessary draft adjustments. Unfortunately, most burner operators also have many other duties that keep them from operating the tepee burner properly. Furthermore, most burner operators are given little or no training in how to operate the tepee burner with a minimum of emissions.

2.2 Maintenance Problems of Tepee Burners

For a tepee burner to operate correctly, all of its physical parameters must be maintained. The shell plates must be tight and free of holes and the access doors must fit tightly to prevent entry of excess air that can reduce the exit gas temperature and cause smoke problems. The access doors often are damaged by the heavy equipment that is normally used to clean out the burner on weekends. The shell plates, screens, overfire air ducts, and access doors are all subject to warping and burning through if the exit gas temperature becomes too high. The shell plates and access doors also can be damaged if burning wood residue piles up against them. If the overfire air vents are warped even slightly, they can become inoperable, making it impossible to regulate and maintain an efficient exit gas temperature.

The thermocouple at the top of the burner also can be damaged by high temperatures. If the thermocouple is not operable, it is difficult to determine whether an efficient exit gas temperature is being maintained.

The underfire air grates or pots must be cleaned at least weekly; otherwise they can become plugged with ash and clinkers. Without sufficient and evenly distributed underfire air, it is very difficult to maintain an efficient fire. The fans for the underfire air system also must be maintained regularly because heat from the burner often reduces their utility.

For a tepee burner to operate properly, it must always be well maintained. However, such maintenance is often a low priority for sawmill operators. If some part of the tepee burner becomes defective or inoperable during the week, there is a very little chance that the remainder of the mill will be shut down until the defect is repaired. Defects often are allowed to exist until they are brought to the mill operators' attention by an Air Quality Bureau Inspector.

In summary, it is relatively difficult and sometimes nearly impossible to operate a well-maintained tepee burner without causing smoke and settled particulate problems. If the tepee burner is not adequately maintained, these problems are almost inevitable.

SECTION 3.0

TRENDS IN THE WOOD PRODUCTS INDUSTRY IN MONTANA

Mills in Montana that continue to employ tepee burners are often comparatively small, many of them processing on the average perhaps 10 million board feet (MMBF) or less of lumber per year. Such mills are especially vulnerable to the vagaries of the wood products markets in the United States. This section establishes the context in which tepee burner mills operate by sketching some of the major trends in the industry and indicating their implications for the smaller mill employing tepee burners.*

3.1 Recent Employment and Production Trends in Montana Timber Production

At the end of World War II, demand for forest products surged in Montana, partly because of the dramatic increase in domestic construction and partly because of the decline of forest yield in many Eastern States. Despite the year-to-year fluctuations in demand characteristic of the industry, the Montana forest products industry grew and diversified over the years, adding pulp, paper, plywood, particleboard, and other commodities to its product line. As prices for lumber products continued to rise, a strong market developed for residuals such as chips and shavings, increasing the efficiency of the industry, reducing the seasonal fluctuation in lumber industry employment, and making yet another marketable product for the mill owner. This increase in efficiency has allowed the industry to employ more people in recent years even though total production of lumber has declined somewhat since the peak year of 1973 (Table 3-1).

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*This section draws heavily on a report prepared by Charles E. Keegan III of the Bureau of Business and Economic Research, University of Montana, entitled Montana's Forest Products Industry: A Descriptive Analysis, September 1979. GEOMET, Incorporated expresses its appreciation to Mr. Keegan and to Maxine Johnson, Director of the Bureau of Business and Economic Research, University of Montana, for their assistance. This section also draws on a report prepared by the Governor's Office of Commerce and Small Business Development, Office of the Coordinator for the Old West Regional Commission, entitled Montana Public Investment Planning Process 1979, July 1979.

Total demand for wood products is closely tied to interest rates and credit availability. These economic factors strongly affect housing starts and associated lumber demand and, to a lesser extent, the paper and particleboard industries. The immediate future of demand for forest products was especially difficult to forecast during the spring of 1980, the period during which this report was written, because of high interest rates and national credit restrictions. Yet both factors suggest a drop, perhaps a dramatic one, in demand in the immediate future for wood products, especially lumber.

TABLE 3-1

MONTANA LUMBER EMPLOYMENT AND OUTPUT

Year	Employment	Output[a] (MMBF)	Output Per Person Employed
1960	7,300	1,035	0.1417
1961	7,400	1,152	0.1558
1962	8,000	1,259	0.1573
1963	8,500	1,166	0.1372
1964	8,400	1,271	0.1513
1965	8,600	1,311	0.1524
1966	8,900	1,375	0.1544
1967	8,700	1,347	0.1548
1968	8,900	1,499	0.1684
1969	8,900	1,397	0.1570
1970	8,200	1,281	0.1562
1971	8,700	1,397	0.1605
1972	9,200	1,311	0.1425
1973	9,800	1,445	0.1474
1974	9,500	1,165	0.1226
1975	8,100	1,038	0.1281
1976	9,100	1,197	0.1315
1977	9,300	1,250	0.1344
1978	10,700	1,260	0.1178
Yearly Average	8,747	1,271	0.1458

[a] The production figure is measured in millions of board feet of cut lumber and does not include processed materials.

Source: Western Wood Products Association and the Montana Department of Labor and Industry

3.2 The Geography of Lumber Production

The vast majority of Montana's lumber is produced in the western part of the State. Counties west of the Continental Divide contributed most of the roundwood products from Montana timberlands. The counties supplying the largest amounts are typically Lincoln with 293 MMBF in 1976, Flathead with 233 MMBF, Sanders with 153 MMBF, and Missoula with 152 MMBF (Table 3-2). Counties west of the Continental Divide yielded about 87 percent of Montana's harvest in 1976, a percentage that has remained fairly constant over the years. Several counties east of the Continental Divide, however, also produced significant amounts. Gallatin, Park, and Lewis and Clark Counties together produced more than 70 MMBF in 1976. Figure 3-1 plots the location of tepee burner mills in terms of Montana employment growth rates by county. In general, such mills are typically located in areas where employment growth rates have been in the upper half of the statewide growth rates.

3.3 Public Versus Private Lands as Timber Sources

Public lands have supplied much of the raw materials used in the wood products industry (Figure 3-2). Public lands include those managed by the U.S. Forest Service, the Bureau of Land Management, the State of Montana, and the Bureau of Indian Affairs. Most of the logging in public lands in Montana has been in the national forests under U.S. Forest Service supervision.

TABLE 3-2

ROUNDWOOD PRODUCTS HARVESTED FROM MONTANA TIMBERLANDS BY COUNTY IN 1976

County	Million Board Feet (Scribner)	Percentage Of State-Wide Total
Lincoln	293	25
Flathead	233	20
Sanders	153	13
Missoula	152	13
Mineral	50	4
Lake	42	4
Ravalli	36	3
Powell	36	3
Gallatin	29	2
Lewis and Clark	28	2
Granite	25	2
Park	21	2
All other counties	71	6
Total harvest	1,169	99

Note: Percentages may not add up to 100% because of rounding.

Source: University of Montana, Bureau of Business and Economic Research, Montana Forest Industries Data Collection System (Missoula, Montana, 1979)

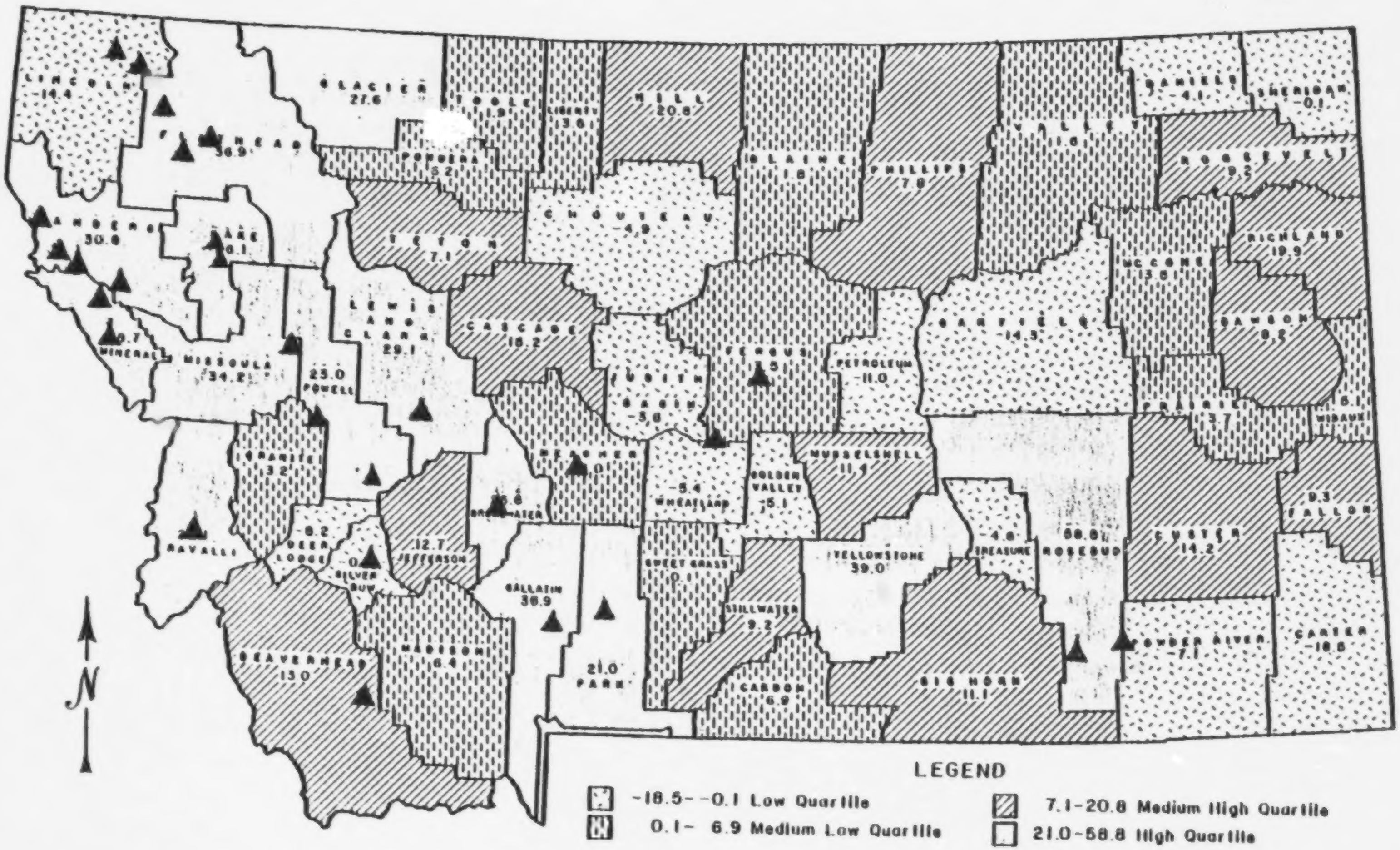

LINCOLN
-14.4
FLATHEAD
36.9
GLACIER
27.6
TOOLE
LIBERTY
3.0
HILL
20.8
PONDERA
5.2
SANDERS
30.8
LAKE
TETON
7.1
CHOUTEAU
-4.9
BLAINE
PHILLIPS
7.8
VALLEY
DANIELS
-4.1
SHERIDAN
-0.1
ROOSEVELT
9.2
RICHLAND
19.9
MC CONE
0.7
MINERAL
MISSOULA
34.2
25.0
POWELL
LEWIS AND CLARK
29.1
CASCADE
10.2
JUDITH BASIN
-3.8
FERGUS
PETROLEUM
-11.0
GARFIELD
-14.3
DAWSON
PRAIRIE
3.7
6.1
WIBAUX
GRANITE
3.2
RAVALLI
-6.2
DEER LODGE
SILVER BOW
12.7
JEFFERSON
BROADWATER
MEAGHER
-5.4
WHEATLAND
GOLDEN VALLEY
-5.1
MUSSELSHELL
11.4
BEAVERHEAD
13.0
MADISON
6.4
GALLATIN
38.9
21.0
PARK
SWEET GRASS
0
STILLWATER
9.2
CARBON
6.9
YELLOWSTONE
39.0
-4.8
TREASURE
58.8
ROSEBUD
BIG HORN
11.1
CUSTER
14.2
9.3
FALLON
POWDER RIVER
-7.1
CARTER
-18.8
N
LEGEND
-18.5--0.1 Low Quartile
0.1- 6.9 Medium Low Quartile
7.1-20.8 Medium High Quartile
21.0-58.8 High Quartile

Figure 3-1

TEPEE BURNER MILLS IN RELATION TO GROWTH IN EMPLOYMENT BY COUNTY
1970-77

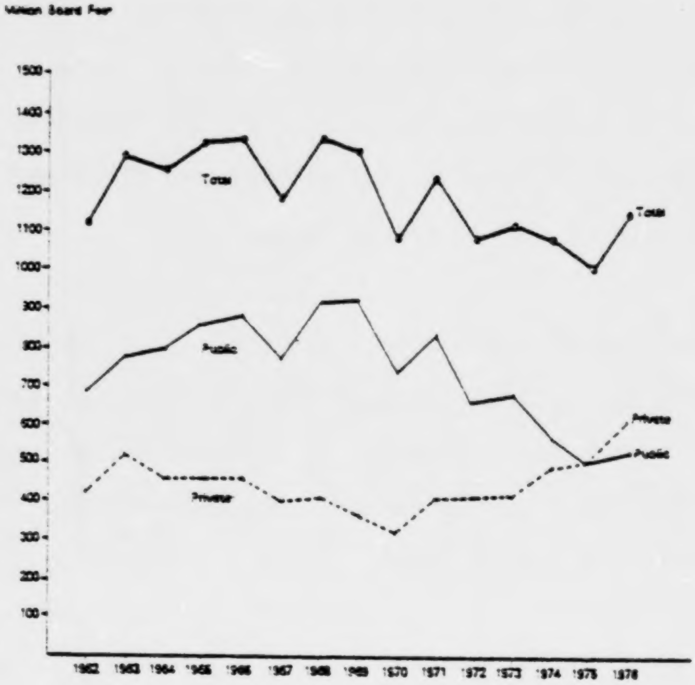
Note: Triangles indicate tepee burner location. In some instances, two or more burners are indicated by a single triangle.

Source: Montana Public Investment Planning Process 1979, submitted to the Old West Regional Commission by the State of Montana, and prepared by the Governor's Office of Commerce and Small Business Development, July, 1979.

FIGURE 3-2

ROUNDWOOD PRODUCTS HARVESTED FROM MONTANA TIMBERLANDS

BY TYPE OF LAND OWNERSHIP, 1962-76



Sources: [1962-68] Ervin G. Schuster, *Montana's Harvest and Timber Using Industry: A Study of Relationships*, Bulletin 41, University of Montana, School of Forestry, Montana Forest and Conservation Experiment Station (Missoula, Montana, 1978) and unpublished data from U.S. Forest Service, Region 1 (Missoula, Montana, 1979); Bureau of Indian Affairs (Billings, Montana, 1979); Bureau of Land Management (Billings, Montana, 1979); State of Montana, Division of Forestry (Missoula, Montana, 1979). [1969-75] Allan L. Hearst, Jr., U.S. Forest Service, Region 1, unpublished data compiled from above-mentioned land management agencies (Missoula, Montana, 1979). [1976] University of Montana, Bureau of Business and Economic Research, Montana Forest Industries Data Collection System (Missoula, Montana, 1979).

The proportionate contribution of roundwood from public lands varies by type of product. In 1976, public lands supplied 51 percent of the saw-log harvest, whereas private lands supplied 49 percent. Private timberlands were the major suppliers of veneer logs, supplying over 67 percent of the total with national forest lands supplying 29 percent and other public lands supplying 4 percent. Almost 58 percent of the output of other roundwood products harvested in Montana was supplied by public lands, and 42 percent of other roundwood products was harvested on private lands.

The significance of these proportions lies in the future supply of accessible forest lands, particularly from the smaller mills' perspective. Possible changes in public land management associated with the Roadless Area Review and Evaluation (RARE) process, and the 1976 National Forest Management Act could reduce access to Federal lands.

Reduced access to such lands would reduce Montana's productive capacity, in the opinion of many in the State's forestry industry. In addition, it could complicate the market position of smaller mill owners, whose access to non-Federal lands is limited. As the next section indicates, the number of small mills has been declining rapidly in recent years.

3.4 Trends in the Size and Number of Sawmills

At the peak of the post-World War II boom in 1956, an estimated 330 sawmills, mostly small, were located in Montana; only 26 of these produced more than 10 million board feet annually.* Since that time, the trend has been towards fewer, but larger, mills. Small mills have declined in number at a disproportionately high rate, as indicated by Table 3-3.

Moreover, sawmills in the various size categories differ in terms of the source of raw materials (Table 3-4). Sawmills in the largest class (Category A--lumber production in excess of 50 MMBF) drew heavily on industrial timberlands and national forest lands for their raw materials in 1976; industrial forests supplied 48 percent of their raw materials, whereas national forest lands provided 42 percent. Other private lands and other public lands in combination supplied only 10 percent.

The mills in Category B (1976 lumber production 25-50 MMBF) were more dependent on national forest lands than were mills in other classes, receiving 56 percent of their logs from national forests. Six percent of their mill

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*Arnold W. Bolle, William K. Gibson, and Elizabeth Hannum, The Forest Products Industry in Montana, Bulletin Number 31 (Missoula, Montana: University of Montana, School of Forestry, Montana Forest and Conservation Experiment Station, May 1966).

TABLE 3-3

NUMBER OF MONTANA SAWMILLS BY SIZE OF PRODUCTION, SELECTED YEARS 1956-76

Year	Under 10 MMBF	10-50 MMBF	Over 50 MMBF	Total Mills
1956	304	26	[a]	330
1966	111	37	[a]	148
1973	86	22	7	115
1976	68	24	6	98
Percent decline since 1956	78	08	NA	70

[a] Mills with lumber production in excess of 50 MMBF have been included in the 10-50 MMBF category for 1956 and 1966.

Sources: [1956 and 1973] Dennis L. Schweitzer, Robert E. Benson, and Richard McConnen, A Descriptive Analysis of Montana's Forest Resources, Resource Bulletin INT-11 (Ogden, Utah: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, January 1975). (1966) Theodore S. Setzer and Alvin K. Wilson, Timber Products in the Rocky Mountain States, 1966, Resource Bulletin INT-9 (Ogden, Utah: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 1970). [1976] University of Montana, Bureau of Business and Economic Research, Montana Forest Industries Data Collection System (Missoula, Montana, 1979).

TABLE 3 4

SOURCE OF SAW LOGS USED BY MONTANA MILLS IN 1976

BY SIZE OF MILL
(millions of board feet, Scribner)

Size Class[a]	Private Timberlands				Public Timberlands				Unknown	All Sources	
	Industrial		Other		National Forests		Other				
A--over 50 MMBF	190,586	(48%)	24,421	(6%)	168,224	(42%)	15,491	(4%)	--	398,722	(100%)
B--over 25-50 MMBF	18,599	(6%)	90,475	(31%)	164,466	(56%)	21,908	(7%)	--	295,448	(100%)
C--over 10-25 MMBF	41,885	(26%)	36,917	(23%)	75,170	(47%)	6,402	(4%)	1,270	161,644	(100%)
D--over 1-10 MMBF	7,229	(22%)	14,550	(44%)	10,087	(30%)	1,540	(5%)	--	33,406	(100%)
E--1 MMBF and below	1,290	(15%)	3,492	(40%)	2,723	(31%)	1,296	(15%)	--	8,801	(100%)
All Mills	259,589	(29%)	169,855	(19%)	420,670	(47%)	46,637	(5%)	1,270	898,021	(100%)

[a] Based on reported 1975 production.

Note: Percentages may not add up to 100% because of rounding.

Source: University of Montana, Bureau of Business and Economic Research, Montana Forest Industries Data Collection System (Missoula, Montana, 1979)

input came from industrial forest lands and 31 percent from other private lands.

Mills in Category C (over 10-25 MMBF of 1976 lumber production) drew more heavily on industrial forest lands than did mills in all but the largest category. These mills received 26 percent of their timber from industrial forests, with other private lands supplying an additional 23 percent. National forest lands were the major source of saw logs for these mills, providing 47 percent of saw logs, with other public lands supplying 4 percent.

The 68 mills in Categories D and E (less than 10 MMBF production in 1976) obtained less of their raw materials from national forests than did mills in the other categories and depended more on private timber, especially from nonindustrial lands. Category D mills obtained over 65 percent of their raw materials from private lands; and those in Category E, almost 56 percent. Tepee burners are likely to be found at mills in Categories C, D, and E.

3.5 Residue Produced by the Wood Products Industry

All wood products manufacturers using roundwood as raw material generate mill residue. In the past, disposal of this residue has been both expensive and a source of air pollution when burned in tepee burners. Burning mill residue is also an enormous waste of wood fiber because only about

60 percent of the total wood fiber delivered to sawmills is actually processed into lumber. With the growth of the pulp and paper industry the particleboard industry and the installation of wood-fired boilers by many wood products manufacturers, most of the residue has now become useful either as a raw material or as fuel.

Plywood plants and sawmills generate three types of salable residue: (1) coarse, chippable materials, consisting of slabs, edges, and trimmings from sawmills and cores from plywood plants; (2) fine residue, consisting of sawdust, sander dust, and planer shavings; and (3) bark. Estimates of these mill residues generated in Montana have been made by the Bureau of Business and Economic Research, University of Montana.* These estimates, based on total 1976 lumber and plywood production, were derived from data gathered by the Montana Forest Industries Data Collection System. Factors expressing the proportion of total raw material that becomes residue were applied to the 1976 figures to determine the volume of the various types of mill residue generated per thousand board feet of lumber or per thousand square feet of plywood. Residue factors were obtained from the Intermountain Forest and Range Experiment Station in Ogden, Utah, and were modified by the Bureau of Business and Economic Research in consultation with mills and manufacturers in Montana to fit the local situation.

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*Charles E. Keegan III, Montana's Forest Products Industry: A Descriptive Analysis, Bureau of Business and Economic Research, University of Montana, Missoula, MT, September 1979, Part II, Chapter 4.

Montana sawmills and plywood plants generated an estimated 1,630 thousand bone dry units (MBDU's) of mill residue in 1976 (Table 3-5), down considerably from the estimated 2,028 MBDU's of total residue generated in 1969. Utilization of mill residue on a percent basis in 1976, however, was up considerably. Utilization on a volume basis declined slightly for coarse residue from 1969-76 but increased for bark and fine residue.

Since 1969, utilization of mill residues has steadily increased. This trend is partly due to improved sawmill technology, spurred by the Sawmill Improvement Program that is jointly sponsored by the U.S. Forest Service and State Forestry Agencies. It is partly because of the increasingly competitive price of wood fiber fuels as compared with fossil fuels, and partly because of the emergence of new products made from wood residue. If current trends in utilization continue, the proportion of wood residue that goes unutilized in Montana will continue to decline, though perhaps less rapidly. If tepee burners can be phased out in a way that converts the wood residue formerly burned into marketable products, this desirable trend will be encouraged.

3.6 Trends in Production by Size of Mill

Since 1956, Montana's sawmill industry has evolved from one in which the lion's share of production was accomplished by a large number of small mills to the pattern today whereby a small number of large mills produce the majority of wood products (Table 3-6). Whereas mills producing less than 10 million board feet per year accounted for 33 percent of total Montana lumber output in 1956, by 1976 they accounted for only about 4 percent. Moreover, by 1976, 81 percent of Montana's lumber was being produced by the largest two categories of mills, whereas the smallest two accounted for only 4 percent of total production (Table 3-7).

TABLE 3-5

ESTIMATED VOLUME OF WOOD RESIDUE GENERATED IN MONTANA SAWMILLS AND PLYWOOD PLANTS COMPARING 1969 WITH 1976

Residue Type by Year		Estimated Volume (000 Bone Dry Units)	
	Utilized	Utilized	Total
Coarse[a]			
1969	698 (87%)	107 (13%)	796 (100%)
1976	658 (95%)	32 (5%)	690 (100%)
Fine[b]			
1969	443 (60%)	297 (40%)	740 (100%)
1976	453 (84%)	87 (16%)	540 (100%)
Bark			
1969	137 (28%)	355 (72%)	492 (100%)
1976	296 (74%)	104 (26%)	400 (100%)
Total			
1969	1,268 (63%)	759 (37%)	2,028 (100%)
1976	1,407 (86%)	223 (14%)	1,630 (100%)

[a] Material suitable for chipping, such as slabs, edgings, and trimmings.

[b] Material such as sawdust and shavings.

Source: Based on Theodore S. Setzer, Estimates of Timber Products Output and Plant Residues, Montana, 1969 (Ogden, Utah: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, March 1971), and University of Montana, Bureau of Business and Economic Research, Montana Forest Industries Data Collection System (Missoula, Montana, 1979).

TABLE 3-6

PERCENTAGE OF MONTANA LUMBER OUTPUT BY SIZE OF MILL FOR SELECTED YEARS BETWEEN 1956 and 1976

Year	Percentage from Mills with Annual Production below 10 MMBF	Percentage from Mills with Annual Production 10 MMBF and above	Total Lumber Output (MMBF)
1956	33	67	979
1962	13	87	1,259
1966	10	90	1,375
1976	4	96	1,176

Source: ¼1956, 1962, and 1966½) Theodore S. Setzer and Alvin K. Wilson, Timber Products in the Rocky Mountain States, 1966, Resource Bulletin INT-9 (Ogden, Utah: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 1970). ¼1976½ University of Montana, Bureau of Business and Economic Research, Montana Forest Industries Data Collection System (Missoula, Montana, 1979).

TABLE 3-7

MONTANA LUMBER PRODUCTION BY SIZE OF MILL IN 1976

Mill Size Class: Annual Production	Number of Mills	Volume (MMBF)	Percentage of total	Average per Mill (MMBF)
A--over 50 MMBF	6	514	44	85.7
B--over 25-50 MMBF	12	433	37	36.1
C--over 10-25 MMBF	12	177	15	14.8
D--over 1-10 MMBF	15	41	3	2.7
E--under 1 MMBF	53	11	1	0.2
Total	98	1,176	100	12.0

Source: University of Montana, Bureau of Business and Economic Research, Montana Forest Industries Data Collection System (Missoula, Montana, 1979)

SECTION 4.0

THE ROLE OF THE TEPEE BURNER IN SMALL SAWMILL OPERATIONS

Those sawmills in Montana still using tepee burners do so for reasons they consider compelling. Without alternatives for the disposal of wood residue, these mills would be unable to continue operations without their burners. This section of the report describes the role that the tepee burner plays in the operations of mills still using them and indicates some possible strategies for phasing out the burners while preserving the viability of the mills.

4.1 A Profile of Mills Employing Tepee Burners

Sawmills in Montana that still employ tepee burners are by no means identical in size, method of operation, markets served, or financial strength. However, a sketch of those sawmills still using the burner is helpful for the perspective it provides on the mills and their problems.

Approximately 30-35 tepee burners are located in the State of Montana, although some of these may not be operational at any given time

TABLE 4-1

NUMBER OF TEPEE BURNERS IN EACH AIR QUALITY CONTROL REGION AND COUNTY IN MONTANA

Air Quality Control Region (AQCR)	Population in the AQCR (1970)	Number of Mills	County	Number of Mills/County
140	135,263	2	Fergus	1
			Wheatland	1
141	144,070	0		
142	167,164	13	Beaverhead	1
			Broadwater	1
			Gallatin	1
			Granite	1
			Lewis and Clark	1
			Meagher	1
			Park	5
			Powell	1
			Silver Bow	1
143	93,221	2	Rosebud	2
144	154,691	18	Flathead	4
			Lake	2
			Lincoln	2
			Mineral	1
			Missoula	1
			Ravalli	1
			Sanders	4

Source: 1978 Directory of Montana's Forest Products Industry Montana Department of Natural Resources and Conservation, Forestry Division, September 1978 because of market fluctuations or for other reasons. Table 4-1 lists these mills according to Air Quality Control Region (ACQR), county, and gross area population. The vast majority of tepee burners, of course, is located in the forested western portion of the State. Of the 35 burners shown, 31 are located in AQCR 142 and AQCR 144, which together contain approximately 46% of Montana's total population (1970 census data). Figure 4-1 shows the geographic distribution of these AQCR's plotted against population growth rates. The size distribution of mills with tepee burners appears below. Twenty-two of the thirty-two mills (68.7%) can be classified as medium to small.

Size In Yearly Production	Number of Mills
More than 50 MMBF	3
25-50 MMBF	7
10-25 MMBF	8
5-10 MMBF	6
3-5 MMBF	3
Less than 3 MMBF	5

Traditionally, sawmills have disposed of the wood residue generated during their operations by burning it. In recent years, the largest mills, and subsequently many of the smaller mills, have been able to market a share of this residue instead. Chips and shavings have been marketed most readily, but the so-called "low value" residues such as bark and sawdust have come into greater demand, particularly as fuel for wood-fired boilers (i.e., hog fuel).

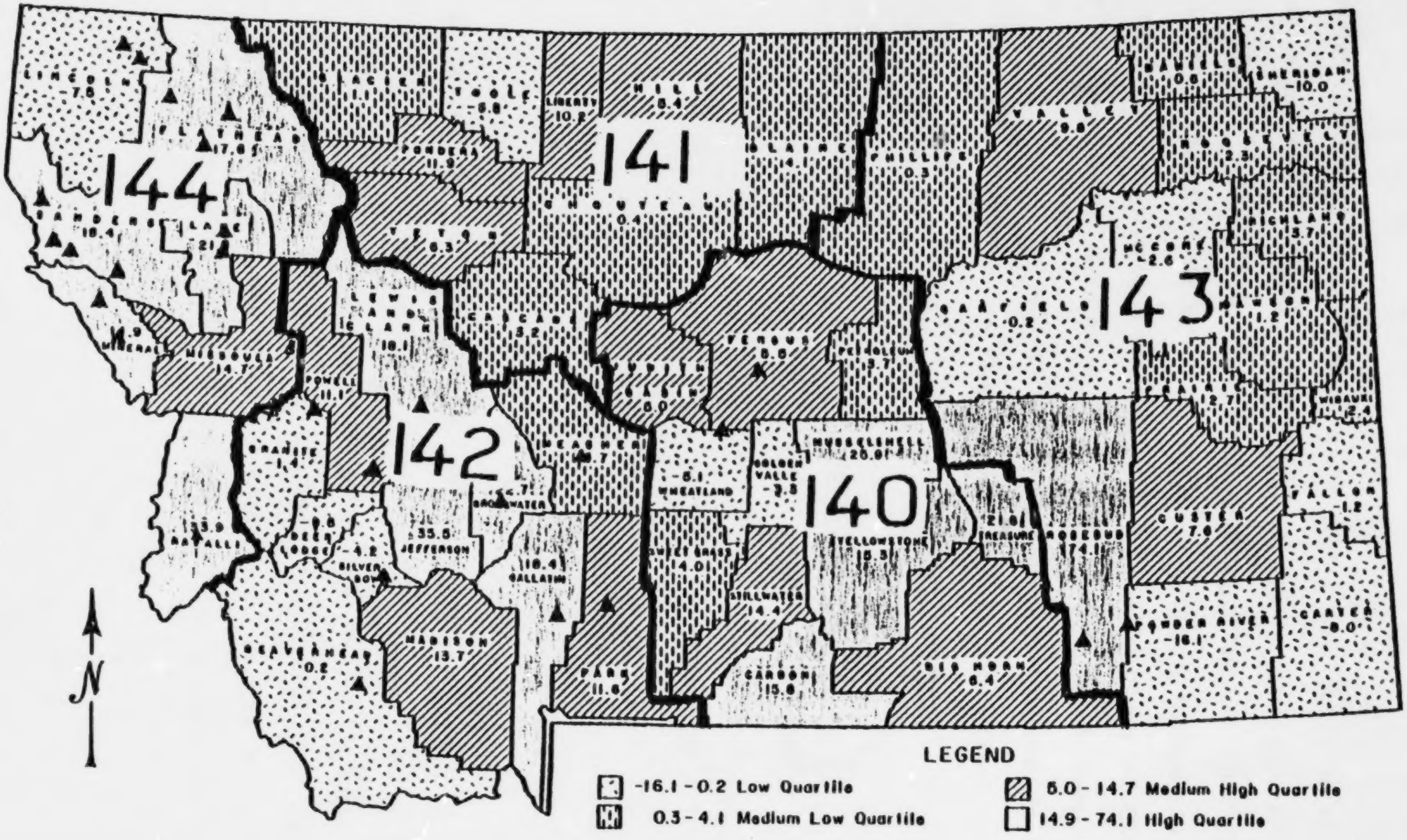
144
141
142
140
143
LINCOLN 7.8
FLATHEAD 17.0
SANDERS 10.4
LAKE 21
MINERAL
MISSOULA 14.7
GLACIER 1.1
TOOLE -5.8
LIBERTY 10.2
HILL 5.4
PONDERA 11.9
TETON 0.3
CHOUTEAU 0.4
BLAINE
PHILLIPS 0.3
VALLEY 9.8
DANIELS 0.6
SHERIDAN -10.0
ROOSEVELT 2.3
RICHLAND 3.7
MCCONE -2.6
GARFIELD 0.2
DAWSON 1.2
PRAIRIE 2.7
WIBAUX 2.4
LEWIS AND CLARK 18.1
CASCADE 3.2
POWELL 11.1
GRANITE -1.4
RAVALLI 33.9
DEER LODGE
SILVER BOW -4.2
JEFFERSON 35.5
BROADWATER
GALLATIN 18.4
BEAVERHEAD 0.2
MADISON 13.7
PARK 11.6
MEAGHER
JUDITH BASIN 0.0
FERGUS 5.0
PETROLEUM 3.7
WHEATLAND -5.1
GOLDEN VALLE -3.3
MUSSELSHELL 20.0
SWEET GRASS 4.0
STILLWATER 14.4
CARBON 15.6
YELLOWSTONE 15.3
TREASURE 21.6
ROSEBUD 74.1
BIG HORN 6.4
CUSTER 7.0
FALLON -1.2
POWDER RIVER -16.1
CARTER -8.0
N
LEGEND
-16.1 - 0.2 Low Quartile
0.3 - 4.1 Medium Low Quartile
5.0 - 14.7 Medium High Quartile
14.9 - 74.1 High Quartile

Figure 4-1

AIR QUALITY CONTROL REGIONS AND MONTANA COUNTIES BY RATE OF GROWTH

Source: Population growth rates from U.S. Bureau of the Census; Federal Air Quality Control Regions from U.S. EPA, Federal Air Quality Control Regions, Rockville, MD, January 1972.

The most systematic estimate of the amount of residue generated by all Montana sawmills (including mills that do not use tepee burners) has been made recently by the Bureau of Business and Economic Research, University of Montana, for the year 1976. Table 4-2 reports their results. Among other things, the table indicates that over 95 percent of the coarse residue (chips and shavings) generated in the State was used productively. The figures for fine residue and bark were roughly 83 and 69 percent, respectively. This suggests that the greatest potential for improvement in marketing wood wastes lies in fine residue and bark. Although there are no systematic data to document the point, it can be inferred from Table 4-2 that the majority of unused wood residue is generated by tepee burner mills.

4.2 Economic Problems Facing Tepee Burner Mills

The trend toward fewer, larger mills discussed in Section 3.0 is partly because of economic conditions in Montana's sawmill industry. In many manufacturing industries, larger firms can often achieve lower per unit costs of production than smaller ones. They are able to do this by using newer, more efficient production processes and equipment, buying materials in larger quantities at lower costs, diversifying their product line so as to minimize downtime when a given market softens, acquiring needed capital improvement loans with greater ease and often at better rates, owning their own timberlands, and spreading their fixed costs over a greater number of salable units.

TABLE 4-2

MILL RESIDUE FROM MONTANA SAWMILLS AND PLYWOOD PLANTS IN 1976
(bone dry units)

Mill Residue	County								Total	Percent of Total Residue
	Broadwater Lewis and Clark Meagher	Beaverhead Gallatin Madison	Flathead	Lincoln	Missoula	Park	Granite Powell Ravalli Silver Bow	Sanders Lake Mineral		
Bark										
Unused	22,311	6,574	21,074	2,160	289	9,435	16,879	27,260	105,982	--
Used										
Hog fuel	--	7,885	46,759	61,278	69,611	--	9,759	42,268	237,560	--
Other	--	--	--	--	--	--	1,182	100	1,282	--
Total	22,311	14,459	67,833	63,438	69,900	9,435	27,820	69,628	344,824	21.8
Fine residue										
Unused	34,955	5,864	5,702	3,384	--	13,061	10,822	16,399	90,187	--
Used										
Hog fuel	--	6,177	61,942	74,138	41,256	--	14,525	16,247	214,285	--
Board plants, pulp, and paper	--	10,611	38,627	17,890	68,254	1,721	18,238	76,439	231,780	--
Other	--	--	--	3,975	--	--	--	--	3,975	--
Total	34,955	22,652	106,271	99,387	109,510	14,782	43,585	109,085	540,227	34.3
Coarse residue										
Unused	840	1,825	3,700	5,320	--	10,576	960	7,710	30,931	--
Used										
Hog fuel	--	827	--	--	17,772	--	--	3,008	21,607	--
Pulp and paper	31,734	17,618	128,006	120,556	202,028	3,199	39,916	90,435	633,492	--
Other	--	827	2,960	--	--	--	--	635	4,422	--
Total	32,574	21,097	134,666	125,876	219,800	13,775	40,876	101,788	690,452	43.8
Residue Totals	89,840	58,208	308,770	288,701	399,210	37,992	112,281	280,502	1,575,503	100.0

Note: One bone dry unit equals 2,400 pounds oven dry weight.

Source: University of Montana, Bureau of Business and Economic Research, Montana Forest Industries Data Collection System (Missoula, Montana, 1979).

During the time the total number of sawmills in Montana declined from 330 (1956) to 98 (1976), almost all the closures were small mills. Moreover, there were only 68 mills producing less than 10 MMBF during 1976, as compared to 304 of them in 1956. The number of mills producing more than 10 MMBF, on the other hand, has been relatively stable, reaching a high of 37 in 1966, declining to 29 in 1973, and then increasing to 30 in 1976.

No studies of Montana sawmills have been done to determine the size of efficient operation. Based on other research, however, rough estimates are available for the upper and lower bounds for efficient sawmill operation. The lower bound appears to be a capacity of approximately 40 thousand board feet (MBF) per 8-hour shift. A study of mills in Oregon, Washington, and California concluded that sawmills below this size were not effective competitors.*

All sawmills in Montana producing more than 10 MMBF in 1976 had 8-hour shift capacities greater than 40 MBF. Almost all mills producing less than 10 MMBF had a capacity of less than 40 MBF per shift (Table 4-3). Between 1956 and 1976, the number of mills with capacities above the efficient size minimum has remained relatively constant. The number of mills less than the estimated

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*W.J. Mead, Competition and Oligopsony in the Douglas-Fir Lumber Industry, (Los Angeles: University of California, 1966), as discussed in Charles E. Keegan III, Montana's Forest Products Industry: A Descriptive Analysis, Bureau of Business and Economic Research, University of Montana, September 1979, Part II, Chapter 2.

TABLE 4-3

LUMBER PRODUCTION AND CAPACITY BY SIZE OF MILL IN MONTANA, 1976

Size Class in 1976	Number of Mills	Production Volume (MMBF)	Percentage of Total	Average/ Mill (MMBF)	Average Capacity/ 8-h Shift (MBF)[a]
A -- over 50 MMBF	6	514	44	85.7	228.5
B -- 25-50 MMBF	12	433	37	36.1	96.3
C -- 10-25 MMBF	12	177	15	14.8	39.5
D -- 1-10 MMBF	15	41	3	2.7	7.2
E -- under 1 MMBF	53	11	1	0.2	0.54
Total	98	1,176	100	12.0	

[a] Computed by GEOMET on the basis of a 12-h working day, 5 d/wk, 50 wk/yr. In the case of smaller mills, this stability of production may be unrealistic.

Source: University of Montana, Bureau of Business and Economic Research, Montana Forest Industries Data Collection System (Missoula, Montana, 1979)

lower bound has declined steadily. This suggests that medium and large sawmills in Montana have an operating efficiency advantage over smaller mills.

This does not mean that Montana sawmills with capacities less than 40 MBF per shift can (or should) be expected to fail. Peculiarities in timber supply, market specialization, or skilled labor, permit some small mills to operate as efficiently as larger mills and to maintain economic viability. In addition, some small mill owners are quite skilled and efficient and may be able to compete directly with larger mills. It does mean, however, that smaller mills typically can be expected to operate under a very delicate balance of financial resources and cannot easily make substantial capital outlays to meet unplanned requirements. This is particularly true in a time of high interest rates and tight credit. Many smaller mills are viewed by banks as comparatively risky loan recipients because of the volatility of the forest products market and the rate at which small mills have gone out of existence in recent years.

4.3 Opportunities for Marketing Wood Residue

Fortunately the market for low value residues appears to be expanding dramatically in Montana. This trend appears to have been gathering momentum since the oil embargo of 1973-74 and the subsequent rapid rise in petroleum prices. In the opinion of most observers of the fuel situation in Montana, there is now a substantial shift from petroleum-based industrial fuels towards fiber-based fuels. This trend is likely to continue in the future at a steady rate because of the continuing rise in petroleum prices vis-a-vis those of wood.

Several specific markets for wood residue now exist in Montana. Champion International's pulp plant in the Missoula area is completing a major expansion of its facility. This expansion will greatly increase Champion's demand for hog fuel for its new boiler during the summer and fall of 1980. The company anticipates that it will "buy about 90 percent of the wood residue produced in Montana" when this expansion is complete during the early fall of 1980*. During the writing of this report, Champion International was in the midst of seeking long-term suppliers of wood residue of all types, including sawdust, bark, and shavings. In this effort, it has contacted most of the mills in Montana and declares itself willing to work with sawmills of any size in almost any location in Montana.

Other possible markets exist as well, though they are not as large or immediate. One is the use of low value residues in processed fuels such as Woodex, Presto-logs and other similar products. At least two comparatively new companies exist in Montana that produce such products. If they are successful in becoming established and continue to grow, they could become substantial purchasers of bark, sawdust, and other low value residue. While writing this report, it was difficult to forecast the probable success of such companies, because their markets and supply source arrangements were still being developed.

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*Statement by Marvin McMichael, Wood-Waste Procurement Manager, Champion International Corporation, to the project team on March 10, 1980.

A third market, somewhat speculative and uncertain in the short run but potentially promising in the future, is the use of wood residue in the production of gasohol. This automative fuel is still in the research and development stage in the opinion of most persons with whom the project team consulted. The technical problems in converting wood residue to gasohol are not difficult, but the production processes needed to produce gasohol at a competitive market price are not yet commercially feasible. Nonetheless, as the price of gasoline continues to rise, it seems likely that such economic problems will be solved, presaging the emergence of a gasohol industry in some form. Wood residue as input to this industry, should it emerge, seems to have an especially bright market future. Other inputs commonly discussed for gasohol, such as grain and other agricultural products, will be in great future demand for other purposes. Wood residue will have comparatively few alternative uses, making it attractive as an input.

Thus, if certain practical problems can be solved, it appears that many small mills currently using tepee burners can instead market their low value residue. They can thereby convert wood residue from a problem that incurs costs and creates air pollution to a product that earns profits (or at least avoids costs) and is pollution-free.

4.4 Practical Problems Facing Tepee Burner Mills that Desire to Market Wood Residue

There are two major problems to be solved. One is purchasing the necessary equipment for converting wood residue into a salable product readily transportable to markets. The second problem is the transportation costs associated with such transport. These problems are discussed below.

The typical mill now using a tepee burner does not have the equipment to convert wood residue into a salable product, nor does it have the storage facilities needed to make truck pickup convenient and economical. These capital improvements can be expensive from the perspective of a small mill (Table 4-4). As the table indicates, a mill would need to purchase a hog (either new or used) to grind up its wood residue into hog fuel. This hog would require installation on a solid concrete pad and would require a conveyor system for transporting the hog fuel to a storage location. Storage could be handled in one of two ways, each of which is convenient for subsequent truck pickup. A mill could purchase one or more "drive under bins". These are the quickest and most convenient storage devices from the trucker's viewpoint because the truck simply drives under the bin, the bottom of the bin is opened,

TABLE 4-4

REPRESENTATIVE CAPITAL COSTS FOR A SAWMILL ENTERING THE HOG FUEL MARKET (prices in spring 1980)

Equipment	Initial Purchase Price[a] (dollars)	Yearly Maintenance (dollars)
Making hog fuel		
New hog	25,000-30,000	1,500
Used hog	7,500-8,500	1,500
Hog installation on concrete pad	5,000-6,000	--
Conveyor equipment (assumed length: 200 ft)	17,000-18,000	500
Storing hog fuel for truck transport using "drive under" bins		
New bin (33-unit capacity)	21,300-22,000	500
Used bins (33-unit capacity)	20,000-21,000	500
Installation	8,500-10,000	--
Storing hog fuel for truck transport using backstop loading dock		
Construction using logs and earth	20,000 plus front loader if not already available	200

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[a] Figures are estimates.

Source: New equipment prices courtesy of the Mill Supply Company, Missoula, Montana. Other estimates provided by various mill operators visited by the project team.

and the stored material drops into the truck bed. Alternatively, a mill could build a backstop loading dock out of logs. Employing such a dock, the truck drives alongside, and the stored material is transferred from the dock to the truck bed using a front-end loader. Table 4-4 indicates that depending on the mix of options selected, the minimum capital expenditures required can range from roughly $49,500 to $86,000, excluding subsequent maintenance costs. Mills with more complicated installation problems, or those seeking greater production and storage capacity, would experience even higher capital costs.

However, once these expenditures are made, the mill should be in a position to market its wood residue. Furthermore, these capital costs should be compared against the year-to-year costs incurred in using a tepee burner. An estimate appears below for a typical, well-maintained burner:

Yearly maintenance needed to keep burner running as efficiently as possible	$30,000
Rescreening the burner every other year	16,000
Additional fire insurance	8,000
Yearly motor replacement	500
Pay for worker to supervise burner operation (5/d at $9/h)	11,250
Total Yearly Cost	$57,500*

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*Source: Estimates by the various mill operators visited by the project team

In practice, of course, not all tepee burners are maintained as efficiently as possible, nor is fire insurance always purchased, so the actual costs to a mill may be lower. But where the maintenance costs are scrimped on, the burner's performance suffers, making it an even greater air pollution problem.

The second major practical problem facing the mill operator wishing to market his wood residue is transporting it to markets. For most mills in Montana, truck transport is the only feasible means of moving hog fuel to markets. The major railroad in Montana, Burlington Northern, does not run lines or schedules that are convenient for most of the mills of the size and location typical of tepee burner mills. Moreover, there is often a transport car shortage in Montana for hog fuel shippers because the railroad tends to transfer cars to the markets and locations at which they bring greater revenue. Under present market conditions, the highest value rail hauls are commodities other than hog fuel and they often lie outside Montana. A second problem limiting the usefulness of train transport is that the rates for hog fuel are based on the definition of hog fuel as a "wood product" rather than as raw material, thereby justifying somewhat higher shipping rates (Table 4-5).

A rule of thumb used by most shippers in the forest products industry in Montana is the that truck transport of wood residue is economically feasible

TABLE 4-5

RAILROAD SHIPPING RATES BASED ON VARIOUS ORIGINS TO SCHILLING, MONTANA[b]

Commodities Transported in Carloads	Montana		Rates in Cents per Unit of 200 cu ft[a]			
	Destination	Origin	E2	E3	E4	E5
Pulpwood Chips, Hog Fuel, or Sawdust	Schilling	Belgrade	2002	2148	2269	2396
		Bozeman	2051	2201	2324	2455
		Brownman Spur	1500	1610	1701	1796
		Cedars	1210	1298	1371	1448
		Dunham	1313	1409	1488	1571
		Dupuis	1362	1461	1544	1630
		Livingston	2198	2359	2492	2631
		Silver City	1660	1781	1880	1986
		Woodlin	1500	1610	1701	1796

E2 - Effective January 1, 1980 and expires with December 31, 1980

E3 - Effective January 1, 1981 and expires with December 31, 1981

E4 - Effective January 1, 1982 and expires with December 31, 1982

E5 - Effective January 1, 1983 and expires with December 31, 1983

[a] Charges on shipments per unit will be based on full loading capacity of car used, determined by dividing the cubical capacity of the car used by unit of 200 cu ft.

[b] Railcar unloading facility at Champion International Plant west of Missoula, Montana.

Source: Burlington-Northern Railroad Commodity Tariff 109. Rates are subject to a 3.5% fuel surcharge plus an additional 1.1% fuel surcharge.

up to a distance of 100 miles and that rail transport is feasible up to about 250 miles at current fuel costs, shipping rates, and market prices for hog fuel. Combinations are possible, however. For example, in the Townsend area, Champion International is building a rail head dump for wood residues that serves as a collection point for wood residues hauled in from surrounding mills. When a sufficient amount accumulates, it can be loaded at Townsend for rail transport to Champion's pulp mill in the Missoula area. Also, a truck/rail transportation system will be used at Colstrip, Montana, to ship wood residues to a Wisconsin paper mill. Similar arrangements are possible in other areas of Montana, thereby extending the range from which Champion can draw hog fuel for its Missoula plant.

Truckers who carry wood residue on an unscheduled basis in Montana work under rates that are negotiated between the shipper and the trucker. In terms of Montana trucking regulations, such truckers are called Class C contract carriers. Because most mills in Montana would ship their residue to a market within the state (due to distance limitations), such mills would either seek to negotiate rates with an available trucking firm or work out an arrangement with a major purchaser of wood residue. For tepee burner mills, the latter strategy is the more likely.

At least two major buyers of wood residue who are willing to enter into such arrangements were contacted by the project team--Louisiana Pacific's particleboard plant (a buyer of shavings, primarily) and Champion

International (a buyer of all types of wood residue, particularly hog fuel), both located in the Missoula area. Both companies are willing to pick up wood residue from small mill suppliers using the trucking company they have under contract. The typical arrangement between such buyers and small mill sellers involves a price for the residue that is a bit lower than the market price to cover at least a part of the shipping cost. If a fair price can be worked out between a tepee burner mill and either of these two major buyers (or perhaps others), this solution to the transportation problem is probably the best available. It requires no public subsidy or other actions, and it capitalizes on the natural incentives of both buyer and seller.

SECTION 5.0

STEPS THAT WILL ENCOURAGE A SHIFT AWAY FROM BURNING WOOD RESIDUE IN TEPEE BURNERS IN MONTANA

Interviews with persons knowledgeable concerning the wood products industry in Montana and a review of available data suggest that there are several low-cost ways to encourage a reduction (and perhaps complete elimination) in reliance on tepee burners in Montana. Most tepee burner mills already wish to market their residue because of the economic benefits of doing so. Almost all are aware of possible markets in which their residue could be sold. Their major problem is meeting the initial capital costs in equipping themselves to market wood residue. It appears that most mills could begin marketing their wood residue successfully by the fall of 1980 if they were able to purchase a hog for grinding up the residue into hog fuel, a storage bin suitable for truck pickup, and the associated auxiliary equipment needed to assure effective operation. As the previous section pointed out, the initial cost of such equipment is substantial, particularly for a small mill operating on a thin financial margin. Several solutions to the problem are described in this section.

5.1 Solutions that Assist Mills in Meeting Initial Capital Costs

Low interest loans and loan guarantees to tepee mill operators are a promising means for assisting such mills. As this report was written, the prime interest rate nationally was at record high levels. Given the market uncertainties facing small mill operators, loan money at even these high rates would typically not be available. Even if available, the repayment schedule would be too demanding given the financial position of most small mills. Fortunately, low interest loans and loan guarantees are currently available under two Federal programs and could be made available under State sponsorship.

Federal Low Interest Loans

The SBA has two low interest loan programs appropriate to the needs of small mill owners: (1) the Regulatory Compliance Loan Program; and (2) the Small Business Energy Loan Program. Each is described below.

The SBA Regulatory Compliance Program

Under Section 7(b)(5) of the Small Business Act, as amended, the SBA may make loans to assist any small business concern in effecting additions to or alterations in the equipment, facilities, or methods of operation of such concern to meet requirements established pursuant to any Federal law, or any State law enacted in conformity therewith, or any regulation or order of a duly authorized, Federal, State, regional, or local agency issued in conformity with such Federal law. The SBA must determine that such concern is likely to suffer substantial economic injury without assistance under this paragraph. An example of such laws is the Clean Air Act of 1970.

A loan applicant must qualify as a small business under SBA employment or sales size standards that are available at any SBA office. Proceeds may be used for new construction, remodeling, or renovation (including equipment) when required to meet inspection standards, paying bank loans used for such purposes, replacing working capital expended for compliance purposes, or helping to finance startup costs and meet continuing fixed costs when operations are curtailed because of construction or changes in methods of operation.

There is no statutory limitation on the dollar amount. Direct loans and the SBA share of a bank participation loan are limited to $500,000, except in cases of extreme hardship. Bank loans guaranteed by the SBA have no dollar limit. Loan maturity is based on applicant's ability to repay, but repayment must be made at the earliest possible date. The maximum term is 30 years.

The private lender sets the interest rate on guaranteed loans and on its portion of immediate participation loans not to exceed a ceiling set by the SBA. The interest rate on direct loans and SBA's portion of immediate participation loans is subject to change, depending on the average annual interest rate on all interest-bearing obligations of the United States. In the spring of 1980, this rate was 8½ percent.

An applicant's financial situation must be sound, and there must be reasonable assurance of repayment ability. Also, the borrower must pledge whatever collateral is available and give security to the extent possible. Applicants must, in appropriate cases, furnish a list of required changes issued by the appropriate enforcing authority (in this case the Montana Department of Health and Environmental Sciences) based on its inspection or review of plans and specifications considered necessary to correct existing violations or other evidence of economic injury covered by the law, regulation, or order. Forms are available from participating banks and SBA field offices.

The SBA Small Business Energy Loan Program

Small business energy loans are available to start, continue, or expand small businesses that are developing, manufacturing, selling, installing, or servicing specific energy conservation measures. Loans may also be made for engineering, architectural, consulting, or other professional services connected with these specific energy measures. Energy loans are not available to firms for installing or undertaking energy conservation measures in their own plants or offices. For this purpose, small firms may apply under SBA's regular business loan program.

Small firms engaged in a number of energy conservation activities are eligible. The applicable areas for tepee burner mills are

- Equipment used primarily to produce energy from wood, biological waste, grain, or other biomass sources
- Equipment for industrial cogeneration of energy, heating, or production of energy for industrial waste
- Products or services using devices that will increase the energy efficiency of existing equipment, or improve operation of systems that use fossil fuels and are on the Energy Conservation Measures List of the Secretary of Energy or approved by SBA on evidence of energy savings

Proceeds of these loans may be used to purchase land for plant construction, for buildings, machinery, equipment, furniture, fixtures, facilities, supplies, materials, or working capital. Generally, energy loan funds cannot be used for research and development.

Direct, or immediate participation loans may not exceed $350,000. Loans under the SBA/bank guaranty program may not exceed $500,000 or 90 percent of the total loan. Repayment period is a maximum of 15 years. A direct loan cannot be made if an immediate participation loan is available and an immediate participation loan cannot be made if a guaranteed loan is available. The maximum size of a loan available to any one borrower will include all other SBA business (but not disaster) loans outstanding with the applicant and all its affiliates.

Although there are no statutory requirements with respect to collateral or security for these loans, an applicant must pledge whatever collateral is available and give such personal guarantees as may be required. Loans must be sound enough to assure repayment, but may have a greater acceptable risk than SBA's regular business loans. Because greater risk is associated with these loans, more emphasis is placed on the technical validity of the product or process; the technical qualifications of the applicant's principals and employees; the quality of the product or service; and the financial status of the firm. Loan funds must not be otherwise available on reasonable terms.

Further details on both these programs are available from John R. Cronholm, Director, U.S. Small Business Administration Field Office, Helena, Montana.

State Low Interest Loan Programs

At present, there appears to be no loan program sponsored by the State of Montana that is specifically oriented towards the needs of small sawmills seeking to eliminate their dependence on tepee burners. However, it might be possible to establish one, drawing on the proceeds of the Coal Severance Tax. Under Montana law, 50 percent of the annual proceeds of this tax is placed in Trust, and 50 percent is available for purposes specified in Section 15-35-108 of the Montana Code. Sections (2)(b) and (j) of the current law appear to be relevant:

(2) Coal severance tax collections remaining after allocation to the trust fund under subsection (1) are allocated in the following percentages of the remaining balance:

(b) Two and one-half percent until December 31, 1979, and thereafter 5% to the earmarked revenue fund to the credit of the alternative energy research development and demonstration account

(j) All other revenues from severance taxes collected under the provisions of this chapter of the credit of the general fund of the state

A loan program that is specifically appropriate to the needs of small mill operators employing tepee burners would probably require action by the State Legislature, which convenes in January of 1981.

5.2 Solutions that Encourage Initial Operating Profitability

It may prove desirable to further encourage operators of tepee burner mills to shift to marketing their wood residue by providing State incentives for such marketing during the first few years after conversion. At least two types of incentives could be explored: (1) tax incentives in the form of rebates to the mill owner per unit of wood residue sold during the first few years after conversion, and (2) accelerated capital depreciation schedules for small mills on the equipment they purchase that allows them to market their wood residue. Each is discussed below.

Tax Incentives in the Form of Tax Rebates to Mill Owners

It may be desirable to permit a special State income tax rebate to small mill owners who begin marketing wood residue after a specified date as a means of encouraging their shift away from wood residue burning. The rebate could be permitted for mills that are medium to small in size, and could be based on the amount of wood residue sold (i.e., the larger the amount sold, the higher the rebate). Such a tax rebate should be temporary and self-terminating. It should be claimable only during the first 2 or 3 years of wood residue marketing, and declining in amount year by year after the first year of eligibility. Tying the amount of the rebate to the amount of residue sold would have the effect of encouraging maximum productive utilization of wood residue. Making the rebate temporary would prevent the establishment of a permanent state subsidy in a market that shows no sign of needing one.

Accelerated Capital Depreciation Schedules for Selected Capital Equipment

It may also be desirable to permit accelerated capital depreciation schedules on State tax for tepee burner mill owners who purchase equipment that puts them in a position to market their residue. Such an acceleration would have the effect of lowering tax burdens on such mills during the first few years of postacquisition operation, thus providing an incentive to purchase such equipment. Accelerated depreciation schedules have the advantage that they are easily targeted on tepee burner mills--the recipient of the tax advantage must purchase the equipment to receive the benefits. The disadvantage is that the incentive effect is not fully felt by the mill owners until several years after the purchases are made, and may therefore be weaker.

5.3 Incentives that Focus on the Transportation Aspects of Wood Residue Marketing

In Montana, only two modes of transportation are significant, truck and rail. Truck transport of wood residue within the State of Montana is done overwhelmingly under rates that are mutually agreed on by shipper and trucker. Transport that goes across state lines does so at rates that are established by the Interstate Commerce Commission. These rates are not readily susceptible to reforms beneficial only to tepee burner mills in Montana. During the course of its work, the project team listened to several suggestions concerning ways to improve the incentives facing truckers, including the allowance of trucks of greater length, greater weight-carrying capacity, and other such concessions. These suggestions for reform, while interesting, did not focus solely on the problems facing tepee burner mills. Moreover, a thorough consideration of their merits would require an examination of the bases for Montana's intrastate trucking regulations, a task well beyond the scope of this report. Accordingly, on the basis of the evidence gathered, there is little room for improving the incentives facing truck transporters of wood residue.

Rail transport in Montana is potentially useful to a comparatively small number of tepee burner mills, especially those mills whose principal market for wood residue is more than 100 miles away (the distance at which rail transport begins to be cheaper per unit per mile than truck transport). Hog fuel made from wood residue is classified by the railroad tariff in the same category as chips, a higher value commodity. It might be desirable to seek a reclassification of hog fuel into a lower cost category as a means of reducing the cost of shipping hog fuel to distant markets. Some tepee burner mills would benefit from such a reclassification, principally those in the Livingston area. But there are two disadvantages in such a strategy. First, it would be difficult to be certain that the benefits would accrue only to small tepee burner mills; and second, lower rates for an important class of cargo might simply encourage Montana's railroads to reduce the number of cars available for such shipments in favor of other cargoes paying a higher return.

5.4 Some Criteria for Choosing the Best Incentive Mix to Solve the Tepee Burner Problem in Montana

The alternative incentive strategies that have been sketched in this section could be applied in various combinations and forms. Criteria for choosing the "best" combination are offered below. They are discussed in greater detail in Appendix D.

- Equity

  The mix of incentives should be fair to all parties concerned. No one should be singled out for special treatment or given substantial public concessions on unwarranted grounds. In particular, there is no evidence that a permanent subsidy is warranted in the current Montana forest products industry. To create one would be inequitable to other participants in the industry who have a history and tradition of economic independence.

- Targetability

  The incentive program selected should be designed so that it meets three "targetability" tests: (1) it focuses on precisely the target population that requires assistance, (2) it renders exactly the assistance required and no other, and (3) the intent of the program is not subverted (intentionally or otherwise) to other purposes.

- Effectiveness

  The incentive program selected should achieve the desired result, which is to help tepee burner mills to shift towards the marketing of their wood wastes. If the incentives are not great enough, public resources will have been wasted without achieving the desired end. If they are too great, a desirable objective will be achieved but at excessive cost.

- Self-Terminating

  As noted earlier, there is no evidence that tepee burner mills require more than temporary assistance to help overcome short-term capital equipment acquisition problems. In view of this situation, the program selected should be self-terminating.

It appears, given these criteria, that the most desirable incentive program would feature the "front-end" incentive of low interest loans to tepee burner mills eliminating their burners, together with the startup incentive of a self-terminating, declining scale tax rebate program operating over the first 3 years of post-tepee burner operation.

APPENDIX A

THE METHODOLOGY EMPLOYED IN THE STUDY

This study was completed employing three major steps. First, the literature was reviewed on tepee burner emissions, on alternative uses for wood residue, and on the incentives available to government at various levels for bringing about desired results. The results of this review appear in Appendices B, C, and D, respectively. Appendix E lists the literature references consulted.

Second, a mail survey was conducted by the State Air Quality Bureau of the mills in Montana using tepee burners. This mail survey gathered information concerning the amount and kind of wood residue burned in each mill, together with other information related to the study.

Third, the ideas and opinions of various knowledgeable persons in Montana were gathered in face-to-face interviews. Persons selected for these interviews are a sample of the major participants and observers in the Montana forest products industry. Interviews with these individuals were conducted by Mr. Dennis Haddow of the Montana State Air Quality Bureau, Mr. Michael Davenport of the U.S. Environmental Protection Agency, and Dr. Michael Harrington of GEOMET, Incorporated. All interviews took place during the period of March 3-14, 1980. The ideas of all these persons contributed substantially to the success of this project, but none of the interviewees is responsible for the specific form or content of this report.

A listing of persons consulted appears below:

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Champion International
Timberlands Division
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University of Montana
Missoula, MT

Richard Webb
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Douglas Williams
Vice President for Cartage
Missoula Cartage
Missoula, MT

APPENDIX B

A REVIEW OF THE LITERATURE ON TEPEE BURNERS AND THEIR IMPACT ON AIR QUALITY

Since roughly 60 percent of the total wood volume that enters wood processing mills is actually converted to primary wood products, disposal of the remaining wood "residue" is necessary. Burning of some or all of these residues in tepee wood-waste burners is a disposal method utilized by some 34 mills in Montana. Although these burners solve the residue disposal problem, they create another, due to their emission of both gaseous and particulate pollutants.

The impact of tepee burners on air quality depends on the (1) volume of material processed, (2) operating conditions during burning, (3) locations of these sources of air pollution and degree of overlap from neighboring locations, (4) ambient air quality levels from distant and other types of sources, and (5) meteorological conditions that affect the transport and dispersion of air pollution on a day-to-day basis.

B.1 OPERATING AND MAINTENANCE FACTORS AFFECTING TEPEE BURNER EMISSIONS

The following emission estimates on combustion of wood refuse in tepee burners are taken from the EPA (1973) guide on emission factors:

Type of Pollutant	Emission Factor	
	(kg/MT)	(16/ton)
Particulates	0.5 (500% excess air, 370°C exit temp)	1.0
	3.5 (1200% excess air, 204°C exit temp)	7.0
	10.0 (1500% excess air, 204°C exit temp)	20.0
Sulfur oxides	0.05	0.1
Carbon monoxide	6.5	13.0
Hydrocarbons	5.5	11.0
Nitrogen oxides	0.5	1.0

However, the quantity of pollutants emitted from these burners may vary tremendously both over time and among burners. According to the EPA (1977)*:

> The quantities and types of pollutants released from conical burners are dependent on the composition and moisture content of the charged material, control of combustion air, type of charging system used and the condition in which the incinerator is maintained. The most critical of these factors seems to be the level of maintenance on the incinerators. It is not uncommon for conical burners to have missing doors and numerous holes in the shell, resulting in excessive combustion air, low temperatures, and therefore, high emission rates of combustible pollutants.

Therefore, operating conditions have a significant effect on the emission of pollutants from these burners. For example, large amounts of excess air will cool the combustion materials, resulting in higher pollutant emissions. Figure B-1 shows the estimated relationship between exit gas temperature and particulate emissions (Corder et al., 1970). Boubel and Walsh (1976) suggested that exit gas temperatures of greater than 600° F will minimize the emissions

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*All references appear in Appendix E.

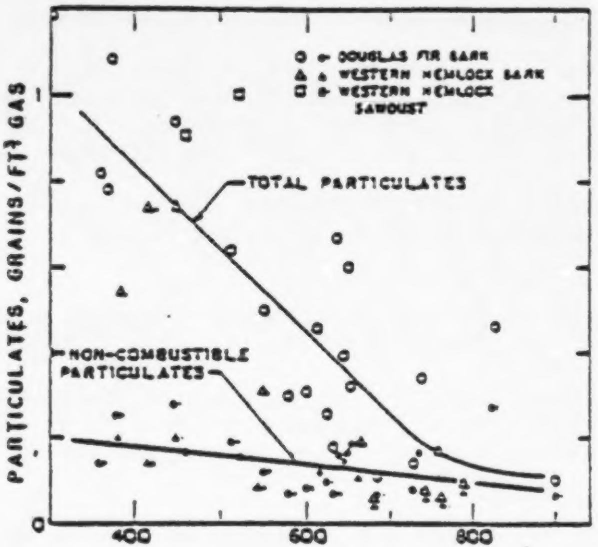

Figure B.1 Gas Temperature At Exit, (Corder, 1970)

of smoke and other particulates and concluded that "the exit gas temperature is probably the best single indicator of combustion conditions and may therefore be relied on as the variable of interest to the operator."

Modifications of tepee burner operating conditions and design that would minimize pollutant emissions have been suggested. Standards for operating conditions have been established in several states other than Montana. For example, the State of Oregon Department of Environmental Quality requires that:

(a) the waste burner size be compatible with the fuel load.

(b) fuel be correctly introduced at a reasonably uniform rate and be of such physical characteristics as not to obstruct passage of underfire air or combustion gases from the heat release within the fuel pile.

(c) an adequately designed underfire air system be provided. Such a system must be adjustable or of sufficient capacity for the maximum rate of fuel supply and must introduce air with sufficient dispersion to preclude channeling through the fuel pile.

(d) adjustable, tangential overfire ports be provided of ample capacity to supply at least 10 times the underfire air volume at a differential pressure corresponding to the burner stack effect at 300° F exit and 90° F ambient temperatures.

(e) the burner shell be reasonably airtight to preclude parasitic leakage and thus cooling effect and lack of control of overfire air.

(f) adequate maintenance practices be observed to assure optimum performance of the underfire air system at all times.

(g) operational practices include frequent adjustment of underfire air volume (firing rate) and overfire air volume as required to maintain optimum exit temperature at all times.

Furthermore, the burner should be cleaned and inspected often to ensure that it is in good repair, and operating logs and temperature records should be kept (Boubel and Walsh, 1976).

Other tepee burner modifications that have been suggested and subsequently rejected include:

- Gas scrubbers
- Fuel drying systems
- Preheating combustion air
- Sprinklers for cinder control
- Refractory linings
- Natural gas or propane mixed with underfire air

Most of the above modifications are either too expensive for a small mill to install or ineffective in controlling pollutant emissions. As a general rule, add-on exhaust control equipment is prohibitively expensive for most mill tepee burners; it is more economical to purchase a new burner fully modified for good control than to install exhaust gas cleaning equipment (Boubel and Walsh, 1976).

B.2 MILL RESIDUE IN MONTANA

Due to its large amount of forested land, a substantial number of wood product companies are located in Montana. The *1978 Directory of Montana's Forest Product Industries* lists 241 sawmills, 79 post and pole processors, 9 plywood and particleboard processors, 1 pulp mill, 25 log home manufacturers, 633 loggers, and 8 secondary manufacturers. Thus, a large amount of wood residue is generated and must be disposed of in some way. Because this study is concerned with the disposal of wood residue by combustion in tepee burners, sawmills using such burners are, therefore, the major topic of discussion. Table B-1 lists the estimated volumes of wood residue generated in Montana sawmills and plywood plants in 1969 and 1976. As this comparison makes clear, the proportion of unutilized residue has been declining steadily in recent years. This decline is due partly to improvements in sawmill equipment and to improved procedures, but also to increased marketability of wood residues. More wood residues can be converted into salable products than ever before, and this trend is expected to continue. Appendix C of this report documents these markets and sketches their technical prerequisites.

TABLE B-1

ESTIMATED VOLUME OF WOOD RESIDUE GENERATED IN MONTANA SAWMILLS AND PLYWOOD PLANTS
1969 and 1976

Residue Type	Estimated Volume (000 Bone Dry Units)			Percentage of Total		
	Utilized	Unutilized	Total	Utilized	Unutilized	Total
Coarse[a]						
1969	689	107	796	87	13	100
1976	658	32	690	95	5	100
Fine[b]						
1969	443	297	740	60	40	100
1976	453	87	540	84	16	100
Bark						
1969	137	355	492	28	72	100
1976	296	104	400	74	26	100
Total						
1969	1,269	759	2,028	63	37	100
1976	1,407	223	1,630	86	14	100

[a] Material suitable for chipping, such as slabs, edgings, and trimmings.

[b] Material such as sawdust and shavings.

Source: Based on Theodore S. Setzer, *Estimates of Timber Products Output and Plant Residues, Montana, 1969* (Ogden, Utah: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, March 1971), and University of Montana, Bureau of Business and Economic Research, Montana Forest Industries Data Collection System (Missoula, Montana, 1979).

B.3 THE NUMBER AND LOCATION OF TEPEE BURNERS IN MONTANA

At this time (Spring, 1980), 35 tepee burners are operating in Montana. Figure B-2 shows the location of these burners in relation to Montana's counties and employment growth. Table B-2 lists the Montana sawmills operating tepee wood-waste burners. As this map demonstrates, the vast majority of these burners are located in the forested western portion of the state. Of the 35 burners shown, 31 are located in air quality control region (AQCR) 142 (13 burners) and AQCR 144 (18 burners). These two regions have respective population of 167,164 and 154,691 and therefore together account for 46 percent of Montana's population (1970 census data). Furthermore, the two burners in AQCR 140, as well as the major population centers of Great Falls and Billings, are located relatively close to this western portion of the State.

Within regions 142 and 144, many burners are located near population centers. For example, seven burners are located in the Columbia Falls-Kalispell area and six burners are located within 26 miles of Bozeman. In AQCR 144 particularly, the burners are located near each other. The fact that these burners are located near population centers compounds their associated air pollution problems.

The size of the sawmills that operate tepee burners is important, since feasible disposal options probably vary among the different size classes. Table B-2 lists the size class of each Montana mill that operates a tepee burner. Approximately 75 percent of Montana's sawmills belong to the smallest size class (A).

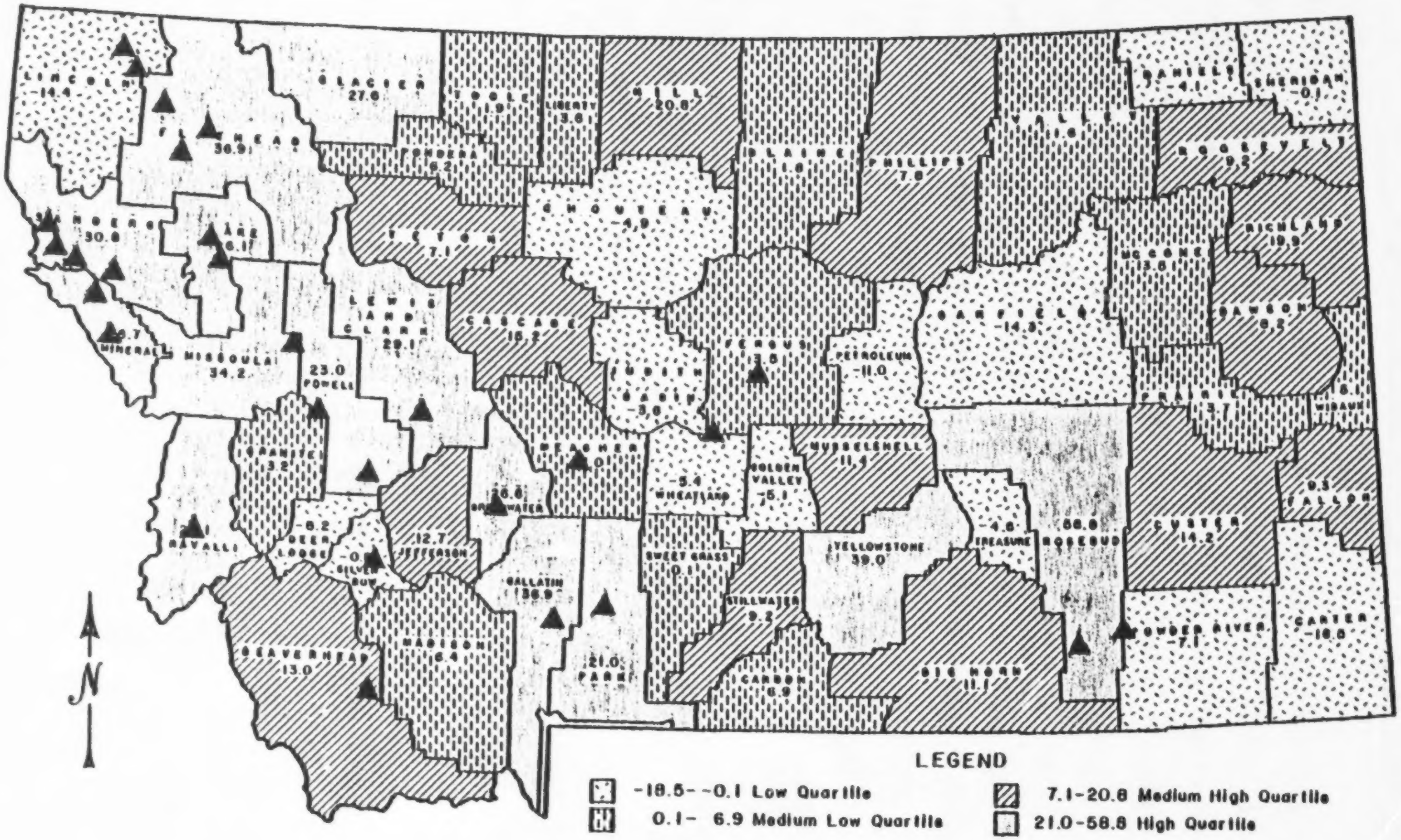
LINCOLN
-14.4
30.9
GLACIER
27.0
TOOLE
1.9
LIBERTY
3.6
HILL
20.8
BLAINE
PHILLIPS
7.8
VALLEY
DANIELS
-4.1
SHERIDAN
-0.1
ROOSEVELT
9.2
SANDERS
30.8
LAKE
6.1
PONDERA
6.2
TETON
7.1
CHOUTEAU
-4.9
RICHLAND
19.9
McCONE
13.6
GARFIELD
-14.3
DAWSON
8.2
MINERAL
20.7
MISSOULA
34.2
23.0
POWELL
LEWIS AND CLARK
29.1
CASCADE
15.2
JUDITH BASIN
-3.0
FERGUS
3.5
PETROLEUM
-11.0
PRAIRIE
3.7
WIBAUX
GRANITE
3.2
RAVALLI
-6.2
DEER LODGE
SILVER BOW
12.7
JEFFERSON
26.6
BROADWATER
MEAGHER
-5.4
WHEATLAND
GOLDEN VALLEY
-5.1
MUSSELSHELL
11.4
SWEET GRASS
0.1
STILLWATER
9.2
CARBON
6.9
YELLOWSTONE
39.0
BIG HORN
11.1
-4.6
TREASURE
58.8
ROSEBUD
CUSTER
14.2
9.3
FALLON
POWDER RIVER
-7.1
CARTER
GALLATIN
38.9
21.0
PARK
MADISON
6.4
BEAVERHEAD
13.0
N
LEGEND
-18.5- -0.1 Low Quartile
0.1- 6.9 Medium Low Quartile
7.1-20.8 Medium High Quartile
21.0-58.8 High Quartile

Figure B-2

LOCATION OF TEPEE BURNER MILLS IN RELATION TO COUNTIES BY EMPLOYMENT GROWTH RATE, 1970-77

Note: Triangles indicate the location of one or more tepee burners.

Source: U.S. Department of Commerce

TABLE B-2
MONTANA SAWMILLS WITH TEPEE BURNERS

MP Key Number	Company	Address	Town	County	Size
AQCR 140	(2 tepees)				
1.	Brand Slumber	Box 1165	Lewistown	Fergus	C
2.	Spring Creek Forest Prod.	Box 128	Judith Gap	Wheatland	D
AQCR 141	(no tepees)				
AQCR 142	(13 tepees)				
3.	FH Stoltze Land & Lumber	Box 389	Dillon	Beaverhead	D
4.	Wickes Forest Industry	Box 675	Townsend	Broadwater	D
5.	Yellowstone Pine Co.	Box 325	Belgrade	Gallatin	D
6.	Sorenson Brothers Lumber	Box 243	Drummond	Granite	A
7.	Champion Building Products	Silver City, Box 854	Helena	Lewis & Clark	E
8.	Castle Mountain	P.O.Box J	White Sulfur Springs	Meagher	D
9.	Brand S Lumber	Box 1033	Livingston	Park	C
10.	Burkland Studs, Inc.	Box 498			C
11.	Park Lumber Co.	Box 1137			A
12.	Donna Lumber	Box 498			A
13.	Willow Creek Lumber Co.	Box 1297			B
14.	Louisana-Pacific Corp.	Box 389	Deer Lodge	Powell	E
15.	Montana Pole	Box 3506	Butte	Silver Bow	-
AQCR 143	(2 tepees)				
16.	Black Lumber Co.	Box 357	Lame Deer	Rosebud	A
17.	Northern Cheyenne	Box 78	Ashland	Rosebud	D
AQCR 144	(18 tepees)				
18,19	Plum Creek Lumber	160 4th Ave. W.	Columbia Falls	Flathead	F
20.	Louisiana-Pacific Corp.	Box 158			E
21.	FH Stoltze Land & Lumber	Box 490			E
22.	Plum Creek Evergreen Division	Box 160	Kalispell		B
23.	Kal-Mont Lumber Co.	Box 1039 NW Dam			C
24.	Klinger	Box 1031			B
25.	Plum Creek Lumber		Pablo		F
26.	Kennedy-Stevens Lumber Co.	Box 986	Eureka	Lincoln	C
27.	Ksanka Lumber Co. Division of Plum Creek	Box 28	Fortine		E
28.	Diamond International Corp.	Box 548	Superior	Mineral	F
29.	Pyramid Mt. Lumber Co.	Box 20	Seeley Lake	Missoula	D
30.	Stoltze-Conner Lumber Co.	Box 415	Darby	Ravalli	D
31.	Flodin Lumber Co., Inc.	Box 309	Plains	Sanders	
32.	Thompson Falls Lumber Division of W.I. Forest Products, Inc.	Box 368	Thompson Falls		E
33.	Watters Brothers Lumber Co.	Box 66			A
34.	Louisiana-Pacific Corp.	Box 1402	Trout Creek		D

Key

Sawmill Sizes
A $3,000 MBF
B 3-5,000
C 5-10,000
D 10-25,000
E 25-50,000
F ¢50,000

Air Quality Control Regions
140 = Billings
141 = Great Falls
142 = Helena
143 = Miles City
144 = Missoula

B.4 LEGISLATION AFFECTING TEPEE BURNERS IN MONTANA

The State of Montana has promulgated regulations that set maximum emission standards for certain pollutants emitted by wood-waste burners and specify other requirements. The two regulations that are particularly applicable to tepee burners are State of Montana Air Quality Rules 16-2.14(1)-S14030 Wood-Waste Burners and 16-2.14(1)-S1470 Sulfur Oxide Emissions. The text of 16-2.14(1)-S14030 follows:

16-2.14(1)-S14030 WOOD-WASTE BURNERS

(1) Construction, reconstruction, or substantial alteration of wood-waste burners is prohibited unless the requirements of the permit rule, ARM 16-2.14(1)-S1415, have been met.

(2) No person shall cause or authorize to be discharged into the outdoor atmosphere from any wood-waste burner any emissions which exhibit an opacity of twenty percent (20%) or greater averaged over six (6) consecutive minutes.

(3) No person shall cause or authorize to be discharged into the outdoor atmosphere from any wood-waste burner particulate matter in excess of 0.1 grains per standard cubic foot corrected to twelve percent (12%) Co_2.

(4) A thermocouple and a recording pyrometer or other temperature measurement and recording device approved by the department shall be installed and maintained on each wood-waste burner. The thermocouple shall be installed at a location six (6) inches above and near the center of the horizontal screen or at another location approved by the department.

(5) A daily written log of the wood-waste burner's operation shall be maintained by the owner or operator to determine optimum patterns of operations for various fuel and atmospheric conditions. The log shall include, but not be limited to, the time of day, draft settings, exit gas temperature, type of fuel, and atmospheric conditions. The log or a copy of it shall be submitted to the department within ten (10) days after it is requested.

(6) No person shall use a wood-waste burner for the burning of other than production process wood waste transported to the burner by continuous flow conveying methods.

(7) Rubber products, asphaltic materials, or materials which cause dense smoke discharge shall not be burned or disposed of in wood-waste burners.

(8) Exception: For building of fires in wood-waste burners, the provisions of section (2) and (3) of this rule may be exceeded for not more than sixty (60) minutes in eight (8) hours. (History. Sec. 75-2-203, MCA; Eff. 12/31/71; AMD, 1978 MAR p. 1732; Eff. 12/29/79.)

In addition, Rule 16-2.14(1)-S1470 states that "commencing July 1, 1972, no person shall burn liquid or solid fuel containing sulfur in excess of one pound of sulfur per million BTU's fired" (State of Montana Air Quality Rules, April, 1979).

APPENDIX C

A REVIEW OF THE LITERATURE ON ALTERNATIVE USES OF WOOD RESIDUE

There are many uses for wood residue other than burning it in tepee burners. Evidence exists that the number of uses is increasing, spurred by the negative incentive of increasingly stringent restrictions on emissions and by the positive incentive of new markets for wood residue. A summary of the various categories of sawmill wood residues and their possible uses appears in Table C-1. This appendix focuses on the major alternatives discussed in the literature under the following two headings:

- Productive uses of wood residue
- Nonproductive uses of wood residue

C.1 PRODUCTIVE USES FOR WOOD RESIDUE

The proportion of wood residue that has gone into productive use has grown larger in recent years, both in Montana and elsewhere in the United States. This fact alone attests to the steadily growing list of productive uses for wood residue. This section discusses the major uses that are now relevant in Montana, or that could become relevant in the near future.

TABLE C-1

PRODUCTIVE USES FOR WOOD RESIDUE

Use	Sawdust	Shavings	Chips	Bark	Users	Market Location	Economical Shipping Distance	Annual Consumption
Fuel								
Hogged fuel	X	X	X	X	Industry--especially forest product industries	Countrywide	Local	Large
Charcoal				X	Charcoal plants			Over 100,000 tons/yr
Briquets	X				Briquetting plants			
Presto logs	X	X	X					
Pulp								
Paper	X	X	X		Pulp mills	Countrywide		Rapidly expanding
Container	X	X	X					
Construction Boards								
Fiberboard	X	X	X	X				
Insulation board	X	X	X	X	Construction industry	Countrywide		Expanding
Particleboard	X	X	X	X				
Soil Amendment								
Fertilizer					Agriculture, nurseries, landscapers, architectural firms	Predominantly rural		
Mulch							Local	Medium, expanding
Other Ground Cover								
Mud control					Construction industry	Countrywide	Local	Small
Decorative bark					Varied	Developed areas		
Erosion control					Highway departments, etc.	Countrywide	Local	
Bedding								
Stable	X	X		X	Farmers, diary	Countrywide	About 50 mi	Large
Cages	X	X			Pet stores, laboratories	Countrywide	Nationwide	Small
Floor Sweeping Compounds	X				Oil, distributed by janitor supply companies to schools, stores, etc.	Urban centers	Up to about 300 mi	Moderate
Metal Finishing	X	X			Sawdust dealers		Usually local	Moderate
Composition Flooring	X	X			Commercial experimentation			Small
Packing	X	X			Shippers, packers	Varied		
Wood Flour	X	X			Specialized plants	Scattered in East, Midwest, West	Up to about 500 mi	About 80,000 tons
Texturizer								
Display window		X				Urban stores		Small, occasional
Wallpaper	X							
Paints					Speciality paint and paper manufacturers			Small
Chemical Extraction								
Pure organic compounds				X	Chemical companies		Local	
Chemical fractions								
Synthetic Abrasives	X				Abrasive manufacturers	Eastern cities	Local	Small
Thermal Insulation	X	X			Builders		Local	Moderate

C.1.1 Pulp Raw Material

At this time, the use of wood residue as pulping material is perhaps most important in terms of market potential, as the pulp and paper industry is the major consumer of mill wastes. Furthermore, this use is increasing nationally at the rate of 10%/yr (Stone, 1976).* In the past, the major raw materials used by pulpmills were roundwood and coarse residues, such as slabs, edgings, and veneer cores, produced by sawmills, veneer mills, and other plants. Recently, because of advances in pulping technology, finer residues, such as sawdust and shavings and in some cases bark, may also be utilized (USDA-FS 1977), depending on the pulping process employed and the desired quality of the end product (Bublitz, 1978). Problems that still remain and on which research should be focused include decreased product yield and product strength with the use of sawdust as a raw material (Bublitz, Yang, 1975) and the presence of specks when bark is included (Styan, 1978).

At least three possibilities exist for the use on Montana's sawmill wood wastes as pulp raw material. First of all, wastes may be purchased by pulp mills already in operation in Montana. The Champion International plant in Missoula is presently a major purchaser of mill wood residue in Montana. Its consumption should increase in the future because of a major increase in its plant capacity during 1980.

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*All references appear in Appendix E of this report.

Second, a survey conducted in 1977 determined that "the Northwest leads in pulping residues from solid wood-processing plants and all Northwest mills report the use of residues" (Bublitz, 1978). In fact, the survey results showed that residues comprised 82% of the total pulp consumption in the Northwest, as opposed to 35% in the Midwest and 40% in the South. The lower figures for the Midwest and South do not reflect an undesirability of residues as raw material or technical problems, but rather the low availability of wood residues in these areas (Bublitz, 1978; Stone, 1976). Perhaps, here is one of the highest profit uses of Montana's wood residues, especially chips. Because pulpwood is a high-value residue use, the cost benefit of longer range hauls to markets make such a possibility feasible where it might not be for other woodwaste uses. In Montana, few mills are unable to sell all the chips they produce.

Finally, the pulp and paper industry itself has projected a national mill residue consumption of 15 million cords by the year 2000. This would mean the consumption of nearly all forecasted recoverable mill and logging residues. However, a problem may remain in that the sites of the projected pulp industry expansion may be far from the residue supply. Therefore, the siting of future pulp and paper mills near major lumber and sawmills may be a profitable solution.

C.1.2 Composition Boards

The composition board industry is a second large consumer of sawmill wood residue. Composition board includes such major products as particleboard, hardboard, and insulation board, as well as more recently developed products. Summaries of the types and quantities of the raw materials used in the particleboard industry appear in Table C-2.

The largest market for western particleboard manufacturers seems to be corestock or industrial board, large amounts of which are shipped to other regions. The use of higher-value residues in composition board is well documented. Only recently has research been focused on the feasibility of inclusion of lower-quality residues in the manufacture of these products. Use of bark has an added advantage in this use, as research has been done on the use of its extracts (to be discussed in more detail later) as bonding agents. Bark also has good insulation properties (Wisherd and Wilson, 1979).

Whether the addition of bark to particleboard manufacturer is beneficial depends on the grade of board, the location of the bark in the board, the type and amount of bark, and the bark-grit content. Thus, underlayment and mobile-home decking seem to be the best uses for particleboard that includes bark. However, in general, it has been determined that because bark is structurally weaker than wood, the addition of bark causes a linear decrease in the strength of the board. It has been determined that high-quality board can be

TABLE C-2

TONS AND PERCENT OF RAW MATERIALS USED BY THE PARTICLEBOARD INDUSTRY IN THE SOUTH AND PERCENT USED IN THE UNITED STATES, 1973*

Type of Raw Material	Tons Used in West (Dry-Weight Basis)	Percent Used	
		Southwest	United States
Roundwood	0	0	7
Venere Core	(1)	(1)	(2)
Planer Shavings	1,858,444	74	65
Plywood Mill Waste	225,265	9	10
Slabs, Edgings, and Trimmings	93,658	4	3
Sawdust	263,796	10	9
Chips	52,109	2	5
Bark	0	0	0
Other	(1)	(1)	1
Total	2,099,611	100	100

(1) Data withheld to avoid disclosure.
(2) Less than one-half of 1%.

Source: Dickerhoof, 1977

made only if the percentage of bark is generally under 20 percent (Wisherd and Wilson, 1979).

Projections made in 1975 call for doubled particleboard and hardboard production and a 50-percent increase in insulation board production by the year 2000 (Christensen, 1975). Lehmann and Wahlgreen in 1978 projected the following construction-related totals for 1980: 212 mill ft^3 for particleboard, 148 mill ft^3 for insulation board, and 0.71 mill ft^3 for hardboards. However, the energy situation may cause a greater increase than expected in insulation board production (Dickerhoff, 1974). This increased composition-board manufacture will increase the utilization of all types of mill residues, especially because Dickerhoff has also predicted the "declining availability of conventional wood furnish for production of boards...." The marketability of these panels are due to their light weight and prefabrication, which saves on labor costs (USDA-FS No. 861).

The extent of the market is important as a determinant both of the demand for the product as well as for the amount of available raw materials. Eighty-eight percent of the raw materials used by Western particleboard plants are in the form of mill residues. Therefore, the status of sawmill production, which reflects the residential construction market, will affect the particleboard production even though this industry has a broader market. Therefore, construction slowdowns will have a large impact on the particleboard industry (Dickerhoof, 1977).

Competition with other products will also affect the composition board market. Plywood may be a major competitor for some of these markets. But, as Schaffer (1976) has predicted, success in marketing sheathing grades products should be especially good after 1980 when softwood plywood products will probably no longer be able to meet its demand.

Competition for the raw material used will affect the industry. Should decreases in nearby mill residue raw materials become a reality, utilization of residues from further distances would become necessary. This could only benefit the sawmill industry in such areas as Montana whose residues may now be considered unavailable as far as the feasibility of long-haul transport in concerned. Although the maximum trucking radius for composition board raw materials a few years ago was 25-50 miles in many areas, it is now up to 100 miles (Wilson, 1975).

The rapid increase in the price of the petroleum-based phenolic resins used as binders in these products will also affect the industry (Schafer, 1976) and will necessitate further research into chemical alternatives, such as those found in bark itself (Anderson et al., 1974). These alternatives will be increasingly important as the adverse health effects of formaldehyde, a component of composition board adhesives, are further documented.

In conclusion, projected increases in the composition board industry, which will necessitate the increased consumption of mill residues, will be a great benefit to the sawmill industry, especially if the new innovations in utilization of sawdust and bark in these products materialize. The extent to which this will affect Montana will depend on where new plants are sited and the value that this industry places on mill wastes as a raw material.

C.1.3 Soil Amendments

The use of wood waste residue as soil amendment is another promising venture. The use of residues is generally restricted to low-value wastes such as sawdust and bark because competition for raw materials from the composition board and pulping industry precludes the use of higher-value residues.

Sawmill residues can be used as a soil conditioner and mixed with the soil, or used as mulch or ground cover. In both cases, the benefits derived are similar, except that soil mixing and nutrient release would be greater in the former case. According to Bollen and Glennie (1961), "The chief benefits to be derived from relatively inert or slowly decomposable wood wastes added to soil are increased moisture retention, greater aeration and better tilth. Mulches retard erosion, hinder weed emergence, reduce evaporation and retain warmth. Decomposition of organic materials on or in the soil results in complex transformations of carbon and nitrogen compounds and eventually supplements the native humus."

However, despite the advantages, many have been hesitant to use wood wastes in this manner. Wood-waste soil conditioners have often been accused of having toxic qualities because of the presence in bark of extractive compounds, such as tannins, resins, and turpentine. This has been disputed by research that shows that any "toxicity" observed is probably because of depletion of available nitrogen (Allison and Anderson, 1951; Bollen, 1969; Bollen and Glennie, 1961; Howard, 1970). Although sawdust in particular may be slightly acidic, the claim of increased soil acidity is probably not warranted.

However, one claim that does have a factual basis is that wood causes a depletion of available soil nitrogen. Although wood contains at least adequate amounts of necessary plant nutrients, it is low in nitrogen, which is required by the soil microorganisms responsible for wood decomposition. (Baxter, undated; Neill, 1976). Fortunately, there are methods to correct this drawback. Nitrogen may be added to the material to bring the soil nitrogen to the 1.2-1.5 percent level that is required to ensure no nitrogen depletion by the microorganisms (Allison, Anderson, 1951; Baxter, undated).

In Montana itself, the use of wood wastes as soil amendments should be of major importance. Montana has a large potential market because of the extent of the agriculture and forestry industries. Also, the amount of processing required for this product is minimal; therefore, no transport to a manufacturing plant is required.

C.1.4 Animal Bedding

As previously discussed, ground bark may also be used as animal bedding (Smith and Paterson, 1976). Pressure on both farmers, because of water contamination by livestock waste, and sawmill operators, because of residue incineration regulations, forced the formulation of a residue utilization project in the Bitteroot Valley of Montana. Advantages determined are: (1) animals remain dry on feet, legs, and udders; (2) the mounds generate spontaneous heat that the animals find comfortable; (3) there are fewer injuries from freezing or slipping; (4) liquids are absorbed into the top few inches of materials; (5) fresh dry material is exposed by scraping off the top few inches with a tractor-mounted blade; (6) if piled and turned in the lot, or dozed to the outside of the lot, the material appears to compost readily; (7) there appears to be no fly or rodent problem; (8) the material stands up well under heavy traffic, forming a corky layer that resists trampling into the mud; (9) the material is easily moved or handled with conventional tractor-mounted manure loaders and spreaders; and (10) it does not mat, as does straw, and the material retains a generally granular handling characteristic, even when there is more than 50 percent livestock waste. After use and compost, the former bedding becomes a greatly enhanced soil amendment (Bergmeir and Bjergo, 1972). According to this study, the major disadvantage is the available quantity of bark waste. If this is true, there seems to be substantial market potential in Montana for livestock bedding that could be tapped more fully.

C.1.5 Physical and Chemical Derivation and Uses

The fractionation of wood wastes into component chemical parts is especially promising over the long run. Bark, in particular, has physical as well as chemical properties that makes it amenable to such treatment. Therefore, it is on this material that most research has been conducted.

Wood is basically composed of cellulose fibers associated with other carbohydrates and lignins and also includes rosin, fats, waxes, and other chemicals. Bark has greater potential in this area, because it also contains tannins and polyflavanoids, and cork, as well as more waxes and distinctive chemical compounds than wood (Herrick, 1971).

Use of Physical Fractions

Although the physical components of bark often differ (Sproull, 1969), these components, cork, fiber, and fines, are the source of many useful products. Cork itself is one such product that is already familiar to the consumer and for which a market already exists. In addition to its established uses, its use as a thermoplastic binder and in insulation and sound proofing in floorings has been suggested (Hall, 1971). Bark fractions have also been used as well-drilling muds or fluids (Chow et al., 1976; Sproull, 1979; Harkin and Rowe, 1969; Hall, 1971).

The physical and chemical properties of bark have suggested its use in trickle filtering because of its capability for ion exchange and physical filtration. Some suggested uses for bark in this filtration capacity include use in sewage plant effluents, pulp mill cooking, cannery wastes, and effluents containing pesticides, fungicides, radioactive materials, and oil wastes. Furthermore, its absorptive capacity for gases may allow bark to be utilized as a gaseous effluent purifier (Howard, 1970; Sproull, 1969; Bergmeir and Bjergo, 1972; Bollen, 1969).

Chemical Extraction

Because of increasing technological sophistication, the extraction and utilization of specific chemical fractions of bark is becoming increasingly important. Goldstein (1976) describes the use of wood in general as a chemical source, and states that wood as a source of carbon can be used to synthesize any organic material and that almost all of the 18 million tons of plastics, synthetic fibers, and rubber produced in the United States in 1974 could be obtained from wood as a raw material.

Bark basically consists of three chemical components: hemicellulose, cellulose, and lignin (Goldstein, 1976; Smith and Paterson, 1976). Through high temperature processes, these components can yield many products that are of great use. A listing of important chemicals derived from lignocellulose and their 1974 U.S. production follows (Goldstein, 1976):

Chemicals from Lignocellulose

	1974 U.S. Production (Millions of Tons)
Total Lignocellulose	
Ammonia	15.7
Carbon	
Methanol	3.45
Hydrocarbon Oils	
Hemicellulose	
Ethanol	1
Furfural	
Cellulose	
Ethanol	1
Ethylene	11.75
Butadiene	1.85
Levulinic Acid	
Lignin	
Phenol	1.15
Benzene	5.55

Extraction of bark with nonpolar solvents can yield such products as waxes, fats, fatty acids, volatile oils, higher alcohol, hydrocarbons, lignorceryl alcohol, lignocenic acid, phytosterol, and beheinic and fesulic acids. Dehydroquercetin, protocatechuic acid, and some flavenoids may be extracted with ether. Ethanol extractions will yield phlobarphenes, tannins, and alkaloids. Tannins, soluble carbohydrates, muscillages and gums, pectins and glucosides, are produced in large volume by aqueous extraction. Sugars present include sucrose, fructose, galactose, mannose, and arabinose. Finally, extractions with sodium hydroxide produces phenolic acid, hemicellulose, and perhaps low lignin polymers, tannins, and phlorphenes (Smith and Paterson, 1976).

The phenolic polymers are at this time considered to be the most important chemical products derived from bark (Chow et al., 1976). An important use of these compounds is as phenol formaldehyde-type adhesives (Sproull, 1979; Hall, 1971; Goldstein, 1976). Much work in the use of bark adhesives has been done by Anderson et al., (1974, a, b, c). This self-bounding property of bark has suggested other possible uses such as in those that are generally termed "molded products,". This property has also made possible the development of bark "pellets," which are basically self-bonded densified bark. Other uses suggested for the polyflavanoid compounds include use as coating agents to disperse and reduce viscosities of suspensions of clay, minerals, pigments and pesticides, and for use in boilers and cooling water treatments because of their ability to prevent corrosion or plugging of pipes (Chow et al., 1976).

Tannin, which is related to the phenolic compounds already described, is an important bark product used primarily in the tanning of leather (Herrick, 1971). However, the market for this product is probably declining as leather products are replaced by products of different composition.

Two other bark products, for which market growth does not seem to be substantial, are rosin and turpentine, which have been produced in the United

States for quite some time. Furfural, which may also be produced from bark, may be used as a chemical intermediate, in lubricating oil refining, or as a solvent (Forest Service, 1976).

The cellulose portion of wood wastes may also be partly or wholly hydrolyzed to sugars, and used as livestock feed. Ruminants, because they possess their own hydrolytic capabilities, are able to digest the partly hydrolyzed material, whereas the requirements of other animals are more stringent. Use of such a product would reduce the quantity of grain necessary for inclusion in livestock diets (Smith and Paterson, 1976; Millet et al., 1976; Harkin, 1969).

The sugars produced in the above-mentioned process may also be used in liquid fermentation systems that produce proteins or chemicals that could be further utilized by the petrochemical industry (Smith and Paterson, 1976). EPA is now involved in a project that would convert cellulosic wastes to glucose by acid hydrolysis. After conversion, the glucose produced would be "transported to fermenting centers for conversion into alcohol or other chemicals" (Energy Users Report No. 310).

Although chemical extraction of bark does seem to be a profitable use of wood waste, particularly bark, there are factors that must be considered before attempting such a venture. First of all, further bark residues will still remain after the desired chemicals have been extracted. Therefore, final residue disposal or use must be included in the overall planning as well as determination of the market potential and feasibility of final disposal (Neil, 1976). Extraction of a single compound is probably not economically feasible, which necessitates the development of a multiproduct technology. Because many chemicals are to be extracted, the market potential of all these products must be determined to judge "the most economic balance of the product mix" (Atherton, 1969).

Although the technology for these chemical applications is not new, such conversion was not economically feasible when petrochemical source costs were low. According to Goldstein (1976), "the recent rapid escalation of petroleum costs along with the recognition that an integrated plant producing products from all wood components could spread the wood costs over multiple products have brought cost estimates for some chemicals from wood into the same range as petrochemicals."

C.1.6 Energy Uses

Energy production from wood wastes may become the most important use of mill residue, especially of bark and other residues that are unsuitable in large quantities for other higher value uses. In the past, wood was a major energy source and still is in many parts of the world. Since 1974, most industrialized countries that rely on nonrenewable energy sources such as fossil fuels, are experiencing rising fuel costs and shortages. This is causing renewed interest in wood as an energy source.

Wood compares favorably with other alternative fuels, but when making such a comparison, the heating value of the particular residue, as well as its moisture content, species, and age must be established because these properties, which may vary widely, affect the value of the wood as fuel (Hall, 1977).

Combustion processes commonly discussed include electricity generation from central plants, onsite steam production, incinerating with municipal refuse, and conversion to other combustion products.

Electrical Generation

Wood-fired electrical generation plants are not very common; however, a few are now in operation. The Eugene Water and Electric Board operates a 32-MW capacity steam-electric powerplant in Eugene, Oregon. It utilizes mill residues for fuel, producing steam and electricity (Berguall, 1978; Grantham et al., 1974). The Burlington Electric Department converted a generator to wood fuel and thereby decreased the electricity production costs to 2.5¢ per kilowatt hour from 3.0¢ per kilowatt hour for coal (Perham 1979). Libby, Montana, is another site of a wood-based plant (Karchesy, Koch, 1979) that is a potential consumer of the mill residues generated in the local area.

In general, the economics of commercial electrical production using wood as a fuel are highly dependent on locally determined factors such as adequate wood supply, demand, and fuel costs. Grantham et al., (1974) determined that "plants of less than 24-MW capacity appear to be too small to operate because scale economy is lost; above 50-MW, fuel supply requirements are limiting" because they would require 100 tons of wood per hour. Others who have noted this 50-MW limit for a single boiler plant include Bergvall et al. (1978) and the Camran Corporation (1974). Thus, siting of such a plant near a mill would perhaps increase the upper size limit because of residue availability and decreased transportation costs.

In later studies, Inmann (1977) determined that "the price of generated electricity at a 220-MW capacity wood-fired power plant ranges from 24 mills to 42 mills per kilowatt hour, at feedstock prices of $1.00 to $2.50 per 10^6 BTU. Such wood-fired plants will probably never compete with large (1000-MW capacity) coal-fired or nuclear plants. Retrofitting small oil or gas-fired power plants to burn wood is competitive with new coal-fired plants of similar capacity or with retrofitting to burn coal. The major opportunity for biomass in electric generation is in small plant retrofit or cofiring with coal in large plants to reduce sulfur oxide control costs."

Many of the problems with the use of wood fuel are the same for both electricity generation and onsite steam production or direct firing and will be discussed later. Some problems unique to electricity generation may limit its feasibility at this time. The efficiency of conversion from wood to electricity is only about 25 percent (Karchesy and Koch, 1979), which is low, especially when considering the volumes of wood required to produce competitive amounts of electricity. Other problems associated with the use of wood as fuel are due to its bulk and volume, which result in higher transportation costs, larger storage volumes (Corder, 1974), and difficulty in handling (Hoff, 1977). This further results in higher capital and operating costs. Although sulfur stack emissions are not a problem as with coal, particulate emission control is a problem that must be dealt with. This, along with additional labor costs, may further add to the operating costs.

However, because the price of fossil fuels is rising so rapidly, the economic feasibility of using wood as a fuel for the commercial production of electricity should be reexamined and the placement of such plants in forest product producing areas, such as Montana, should be studied.

Use as Fuel for In-Plant Processes

Despite the limited utilization of wood as a fuel in this manner, the use of wood for steam production in the forest product industry itself has proven quite successful. The advantages of onsite fuel availability, at no cost, mill experience with handling of this fuel (Karchesy and Koch, 1979), reduction or elimination of other fuel costs, and variability of other wood waste markets make this a very attractive possibility. Elimination of residue transportation costs is another major benefit (Grantham, 1978).

Many sawmills and other wood-product manufacturers that create a large volume of wood residue might be able to acquire energy self-sufficiency by the use of wood as fuel. However, because fuel is still a relatively low-value residue use, it may be advantageous to confine the use to such low-value wastes as sawdust and bark. Because of their high resin content, the latter has a higher heating value than wood.

Recently, examples of such in-plant residue use as fuel have been published. Lane Plywood saved $2,300 (1973 prices) in gas fuel costs for 1 month by the installation of an Energex Vortex burner that utilizes all available sander dust (White, 1973). A fully automatic boiler that produced steam from sawdust and bark fines was installed at the Coin Lumber Company. This boiler eliminated a $380,000 annual oil bill (1974 prices). The addition of a 1500-MW steam-driven generator was being considered at the time and may now be in production. This company also disposes of its other residues by exporting its chips, selling its planer shavings for particleboard production, and bark to a decorative bark product manufacturer, as well as excess hog fuel to other plants, exemplifying the potential product mix that can be marketed (Blackerby, 1974). The KW Muth Co. of Sheboygan, Wisconsin, which produces various composition board and other board products, uses its waste as fuel, "generating a net 5.5 million BTU's per hour, disposing of 90 percent of the firm's waste products and saving an estimated $53,000 in fuel and waste-hauling costs the first year" (Anonymous, Pulp and Paper, 1977). And, in Montana itself, Champion International of Missoula supplies 84 percent of its power needs by burning waste wood from its plywood mill. It has similar plans for its Dee, Oregon, plant.

Pulp and paper mills are by far the largest energy user in the forest product industry (USDA-FS 1976; Arola, 1976). Because they mainly consume, not produce, wood waste, "package-deal" sales of mill residues to the pulp mills should be a profitable enterprise. Sawmills could sell all grades of wastes to the pulp mills, which would use the suitable residues for pulping, and burn the remaining portion as fuel.

Cogeneration

Further advantages may be realized by the forest product industries if generation of electricity is combined with process steam production. These plants could utilize some electricity produced and sell the excess to local energy consumers or utililities. This combination of processes is commonly termed cogeneration. Because what would normally be waste heat is utilized as process steam for the plant's own use, the overall conversion efficiency may be increased from 25 to 50 or 60 percent (Grantham, 1978). This process steam may be used for direct drying (of both wood products and the fuel itself) as well as for heating and cooling (Johnson, 1977).

A further possibility is the combustion of wood in combination with fossil fuels, particularly (in Montana) natural gas. A large plant without a sufficient wood supply might choose this alternative (Hall et al., 1977). The goal of energy self-sufficiency in the forest product industry may be met through the use of wood as fuel. The attainment of this goal would reduce the problems of both declining fossil fuel costs and supply.

C.1.7 Energy Conversion

The fuel potential of wood waste is not confined to direct combustion in boilers or other combustion devices. Much research is currently being done on conversion of these residues into other energy forms. However, one disadvantage of conversion of solid waste to other forms, such as gases or liquids, is the loss of energy in this process (Corder, 1976). Some of the processes discussed below are still in the development, testing, or commercially unfeasible stage.

Gasification

Gasification may be the most promising conversion possibility for wood wastes. This process entails the production of gases such as carbon monoxide, hydrogen, and methane from wood wastes (Halak, 1977, Karchesy and Koch, 1979, Bergval et al., 1978). There are quite a few reasons for the potential of gasification of wood wastes. Although the capital expense of a gasification plant and incineration systems are similar, the gas has a higher thermal efficiency and lowered pollutant emission. Another benefit of wood gasification is that the "synthesis gas (hydrogen and carbon monoxide) can be used to produce several important chemicals and fuels. Methane, hydrogen, ammonia, methanol, ethylene glycol, and gasoline can be made directly from synthesis gas. Additionally, a high-octane gasoline can be produced from methanol in a one-step process" (Karchesy and Koch, 1979). Such a plant has been tested in Stockton, California, in 1977. The estimated capital costs of this type of plant, producing 130 million BTU's per hour was $300,000. The cost of the gas produced may be less than $1.00 per million BTU's (California Energy Resources Conservation and Development Commission, 1977), although the output will vary with the original moisture level and material type (Hodaw, 1978).

Albert Industrial Developments, Ltd., has a "Thermex Reactor which produces both gas and charcoal, the respective amounts of which can be varied" (Halak, 1977). Hammond et al., have also studied the wood-gasification process and "processing about 200 bone-dry metric tons of wood waste (45 percent moisture content) per day, they estimated an operating cost of $6.60-9.90 per bone-dry metric ton and an energy conversion efficiency of 80 percent" (Corder, 1976).

Michael Antal at Princeton University has recently developed a method to convert cellulosic wastes to hydrocarbon fuels using "silvered mirrors" that concentrate sunlight. The gases produced include ethylene, hydrogen, and carbon dioxide (Environmental Science and Technology, November 1979).

Conversion to Crude Oil

The conversion of wood chips to crude oil is another possible energy use of mill residues. However, more research is necessary before this process becomes feasible because at this time the process uses more energy than is produced. Bechtel Corporation of San Francisco is operating such a plant in Albany, Oregon, for the Department of Energy on a test basis (Karchesy and Koch, 1979).

Conversion to Methanol

The conversion of wood wastes to methanol is another possibility. Up to 15 percent methanol can be added to gasoline without requiring automobile modifications. It may also be burned as fuel and can be used in fuel cells that generate electricity (Bergvall, 1978). Major industrial use of methanol is in formaldehyde conversion and as a solvent and in plastic manufacture.

In the future, decreasing amounts of natural gas and other priority uses of coal, which are the present primary methanol sources, may increase the use of wood wastes in this process.

Conversion to Ethanol

Ethanol, which at the present time is primarily produced from the petrochemical ethylene and industrial and beverage fermentation, may also be produced from wood (USDA-FS, 1976 and Bergvall, 1978). Ethanol may be used as a motor fuel additive in addition to its use in chemical manufacture, toiletries and cosmetics, acetaldehyde, and industrial solvents and detergents.

Capital costs for ethanol plants using wood as a source are about three times higher than those utilizing ethylene or grain. Although both wood and grain-based plants utilize the fermentation process, because wood contains 50 percent of the sugar of grain, the capital production costs of the wood plant are therefore higher.

Research into the degradation of cellulose may produce technological advances that will help to lower costs of ethanol production. A recent development in this area is the discovery by University of Georgia researchers of bacteria that are able to degrade cellulose to ethanol (Energy Users Report No. 314). Finally, a $92,000 grant that would finance "pilot projects to study various alternative energy sources in Montana" has been suggested. Twentyfive thousand dollars of this grant would support a plant at Thompson Falls that would produce alcohol fuel from waste wood (Great Falls Tribune, 12/9/79).

C.1.8 Wood Densification

The high volume of wood residue is often mentioned as a deterrent to further utilization. Therefore, the densification of wood wastes into briquets is a promising development. Such a densification has two major benefits: transportation costs may be reduced because the volume and weight transported are lessened (Steffenson, 1973); and in the case of fuel applications because energy content is increased (Steffenson, 1973; Sprout-Waldron and Co., 1961). Specifically, densification of bark is highly promising because of its self-bounding properties.

Products manufactured include fuel logs such as Pres-to-logs, the industry standard (OSU, 1977; Steffenson, 1971), and Fire-Glo, produced by Agnew Environmental Products (Pease, 1972); stoker fuel (OSU, 1977); pellets such as Woodex; and charcoal (Blackman, 1978).

Other possible benefits of these pellets and other such products are ease of storage and lowered transportation costs (due to decreased volume), lowered conveying cost (due to ideal shape), ease of packing, and potential of lowered labor costs due to automatic firing (Steffenson, 1973; Currier in Spokesman-Review, April 19, 1972; and The Portland Oregonian, April 20, 1972).

These pellets may be used in conventional boilers as well as in other combustion devices and dryers (Steffenson, 1973). Construction of a 40,000-50,000 KW capacity electric generating plants, to be fueled by woodex (composed of wood and agricultural waste), is scheduled for July 1980. The plant will be located in Madera, California and is expected to begin operation in July 1981. (Energy users Report No. 345). Homeowner use is increasing. A firm in Vermont is currently developing a small gasification furnace using pellets for home heating (Perham, 1979). Pellets have other uses besides as an energy source. Nutrients may be added to densified bark or wood, which then serves as a fertilizer medium. Addition of insecticides or fungicides to these pellets is another possibility (ITF-FSU, October 5, 1977). Although a discussion of pellet compost was directed at municipal refuse, this concept could probably apply to wood waste as well (Fuller, 1966).

The production of briquets from charcoal is a potentially profitable venture, as these briquets have found use in homes and especially in outdoor recreational cooking. Charcoal has other uses, however, such as in the manufacture of carbon disulfide, carbon tetrachloride, sodium cyanide, and other industrial chemicals.

C.2 NONPRODUCTIVE USES OF WOOD WASTE

This section discusses methods of wood waste disposal that do not result in the production of a marketable product. Such methods include alternative incineration methods, burial of wastes, and residue reduction.

C.2.1 Other Incineration Methods

Alternatives to burning wastes in tepee burners are discussed by Boubel and Walsh (1976). These includes fuel bin, multiple chamber, and open pit or air curtain destructor systems. The fuel bin system differs from a tepee burner in that it stores the wastes that are not being burned at a given time. The multiple chamber system is the most efficient incinerator type, but wastes must be reduced in size before use. Lastly, the air curtain destructor has often been discussed as a replacement for the tepee burner. Problems associated with this system include inability to burn small-sized wastes and unacceptable particulate emission (Hoyt, 1975).

Because the predominance of tepee burner systems in Montana at this time may be due to favorable cost factors, it is likely that the use of other systems will be more costly for some mills. This is especially true of the multiple-chamber system that may cost 10 times as much as the tepee burner. However, the reduction in incinerator size that is prompted by the fuel bin system may compensate for the additional costs of waste storage and increased hours of operation necessary (Boubel and Walsh, February 1976).

Many of the air pollution problems associated with any incineration system, including tepee burners, will be encountered with these systems also; therefore, other disposal methods should be sought if air quality is to be enhanced in Montana.

C.2.2 Burial of Wood Waste

Although burial of wood wastes solves the air pollutant emission problem of tepee burners, this disposal method also has disadvantages and environmental impacts. Pollution of the groundwater may occur, especially if the wood waste is deposited below the water table (Sweet, 1975). Other environmental effects to be considered include potential mechanical injury to trees through disturbance and breakage of roots and subsequent increased susceptibility of the disturbed vegetation to fungus infections and other diseases. The area that has been disturbed may become nonproductive if topsoil is not properly replaced (Ward, 1976) and erosion may occur. Once the wood waste is buried, decomposition, settling of the burial site, and the possible production of methane gas must be considered (Evans, 1973).

Cost is another factor to be considered. Capital outlay may or may not be necessary depending on whether the burial equipment is bought or rented.

Either way, operating costs will include increased labor and perhaps equipment rental. The tremendous volume of wood wastes generated, even if most were disposed of in alternative ways, would entail progressively more distant burial sites, resulting in increased transportation costs. This transport, as well as the actual burial process, might further disturb the ecosystem. Furthermore, burial is usually not possible in rocky areas or on steep ground (Schinke, 1966). The winter stoppage might necessitate a large onsite storage capacity, especially in areas such as Montana.

C.2.3 Residue Reduction

Perhaps the most obvious solution to the wood-waste problem would be the reduction of the amount of sawmill residue produced. Such a trend has been projected, due to technological advances in yarding systems, presence of log-sorting centers, new pulping systems, and finer, more accurate sawing (Adams and Smith, 1976). Dickerhoof (1975) has predicted advances in technology that would accomplish a 23-percent decline in shavings volume and 36 percent in sawdust volume in the next 5-15 years, depending on the availability of investment money.

APPENDIX D

A REVIEW OF THE LITERATURE ON GOVERNMENTAL INCENTIVES THAT MIGHT BE USED TO ENCOURAGE ALTERNATIVES TO BURNING WOOD WASTE IN TEPEE BURNERS

There are three broad alternatives that government at various levels might use to create or reinforce desirable incentives concerning disposal of wood residue in the forest industry. They are (1) employing governmental programs that subsidize or otherwise encourage desired activities in the industry, (2) altering the tax structure for producers or users of wood waste, and (3) employing direct regulation to achieve desired results. All three alternatives have a long history in various U.S. industries, and the literature suggests that each has strengths and weaknesses in the forest industry. Relevant aspects of this literature are reviewed under the following major headings:

- Possible incentives that can be created by governmental programs
- Possible incentives that can be created by changes in the tax structure
- Possible incentives that can be created by regulatory activities

D.1 POSSIBLE INCENTIVES CREATED WITH GOVERNMENTAL PROGRAMS

A vast amount of literature exists on ways in which government at various levels can reach desirable public goals by spending money.* Those that are plausible for encouraging desirable means of wood residue disposal are discussed below.

D.1.1 Direct Subsidies

First, direct subsidies to wood residue sellers, buyers, or transporters might be considered. Such subsidies could be achieved in various ways. The State government could purchase wood residue directly, perhaps for subsequent use as an energy source or for other purposes. The current use of wood residue to heat several State university campuses in Montana exemplifies this approach. Or an appropriate governmental agency might pay for a portion of the capital equipment that mills require to shift from tepee burners to more desirable methods of disposal. Or the agency might undertake to pay a portion of the transportation cost associated with moving wood residue from mill to markets. Still another possibility is to guarantee the minimum market price at which wood residue can be sold, much as the USDA does for many agricultural products. Such strategies might be especially effective if the wood residue market in question is just on the verge of being economically self-supporting. In such situations, a public subsidy, perhaps even a small one, can be just enough to assure that a market exists for the wood residue.

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*See, for example, discussions appearing in the Brookings Institution series, Setting National Priorities, published each year since 1971, which analyzes the effects of the Federal budget on public policy objectives.

On the other hand, public subsidies such as this are often criticized on grounds that (1) they represent an unfair use of governmental buying power on behalf of the "special recipients" who reap the resulting benefits; (2) they run the risk of being permanent, rather than a temporary "priming of the pump;" and (3) they interfere with the normal market place in ways that tend to promote waste and inefficiency (Musgrave, 1973).*

D.1.2 Loan Guarantees

A second possibility is for the Federal or State government to offer low interest capital improvement loans to target businesses. The U.S. Small Business Administration (SBA), among other Federal agencies, has substantial experience with this broad strategy. In particular, under its Regulatory/Compliance and Small Business Energy Loan programs, SBA makes loans to regulated industries that must meet the requirements of the Clean Air and Toxic Substances Control Acts. This alternative is often desirable in situations where the target business will be able to operate as desired once the initial (but sometimes high) capital improvements are made. In the present context, many small Montana mills now using tepee burners (or other forest products manufacturers for that matter) can successfully produce marketable products from their wood wastes if they can purchase the necessary equipment. In a time of high interest rates and tight money, the offer of low interest loans (SBA's rate is currently 8¼ percent) might provide a substantial incentive. Loan guarantees in such forms as the Industrial Revenue Bonds are a variation of this strategy.

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*All references appear in Appendix E.

Experience with publicly subsidized loans suggests that if they are to work effectively at reasonable cost to the public, several prerequisites must be met so that they can achieve the desired end. They should not be offered on such favorable terms that money in the capital market is diverted from other desirable purposes. One of the most important prerequisites, however, is subsequent viability. The demand for the product made available as a result of the use of the loan (in the present case, marketable wood waste) must be sufficiently high to assure the economic viability of the product once the investment is made. In other words, public programs should never make loans to a dying industry. Some have argued that low interest loans are unnecessary except in times of natural disaster. If an investment is a good one, runs this argument, the capital markets will find a way to fund it. If it is not, the project will usually fail, with or without subsidized loans (Davie and Duncombe, 1972).

D.1.3 Market Creation Strategies

A third type of direct expenditure involves government programs to assist in the creation of a market for the wood residue. An example of this strategy is embodied in the proposal introduced by Montana Senator Melcher on November 9, 1979 (Senate Bill 1996). This bill would "pay timber purchasers for their costs in the removal and processing of wood residues from U.S. National Forests to points of prospective use as fuel, or conversion to use as industrial hydrocarbons, alcohols, petrochemical substitutes, or wood products." Another example is the proposed U.S. Forest Service Young Adult Conservation Corps, which, among other things, would improve access to national forests for purposes of recovering marketable wood waste. Both these initiatives focus on the supply side of the market. They seek to increase the amount of wood waste available for marketable purposes. As such, their short run effect might be to drive down the price of wood waste. But as wood-waste fuels become increasingly competitive with petroleum fuels, the shift from the latter to the former may accelerate among U.S. industries. The result could be an even stronger market for wood waste (Bergvall et al., 1979).

D.1.4 Research and Development Projects

The fourth strategy involves funding research or demonstration projects that develop or demonstrate the feasibility of some key aspect of the market. For example, there are numerous such research and demonstration projects being funded by government at all levels focusing on the conversion of wood waste into gasohol. If successful in both technical and economic terms, such projects would promote the development of a strong market for wood residue.

Historically, research and development (R&D) has been one of the most successful and politically defensible uses of public money, particularly when directed toward applied research projects. The advantages of such programs usually cited are that they promote innovation by lowering the economic risk to the private sector associated with new ventures and they allow experimentation with technologies or production procedures that many industries could not support long enough to prove (or disprove) their value. The principal criticisms of such programs usually involve arguments over the desirable balance between "basic" and "applied" research, and whether "sufficient" money is allocated to projects that promise immediate economic gain. It should be possible to devise R&D projects focusing on wood residue uses that capitalize on these advantages without suffering the disadvantages.

D.1.5 Information Gathering and Dissemination

A final strategy requires that the government fund information gathering and dissemination programs aimed at benefiting buyers or sellers of wood residue. Such programs would inform these buyers or sellers of the existence of an emerging market for wood wastes, the availability of a new technology that would make a market more competitive, the existence of new government technical assistance programs designed to improve the market, the range of tax credit or subsidy programs available to business that deal in wood wastes, or other such activities. The buyers or sellers of wood residue might be so informed through governmentally sponsored pamphlets, "market fairs," statistical summaries of relevant business sectors, and the like. This strategy can be quite effective, if well planned. It is subject to less possible criticism than some of the other strategies, since it is comparatively cheap and most people regard the dissemination of economic information as a legitimate, highly desirable governmental activity.

D.2 POSSIBLE INCENTIVES CREATED BY CHANGES IN THE FEDERAL OR STATE TAX LAWS

An equally vast literature exists on ways in which government can encourage or discourage industry behavior through use of the tax system. Here again, attention will focus on those methods that have potential value in the Montana forestry industry.

D.2.1 Early Year Tax Reductions

Government could encourage the adoption of alternative methods of disposing of wood residue by reducing or even eliminating an appropriate tax paid by those wood producers who adopt environmentally sound disposal methods. Both income and property taxes have been used this way, of course, for many years (Pechman, 1974). This incentive could be established for the first year of the producer's changed operation, or it could be retained indefinitely if necessary. Several methods have been used to reduce taxes. For example, the tax could be reduced by the same percentage as the reduction in wood residue burned in tepees during a given tax year. This method might provide an especially effective incentive for small mills, which currently burn much of their residue. Or the tax might be reduced by a fixed dollar amount per unit of wood residue disposed of in an environmentally benign fashion. Other possibilities exist as well.

For this kind of incentive to be effective, the tax reduction must be sufficiently large to offset substantially the cost to the mill owner incurred in shifting to the desired alternative. Furthermore, the provision of the tax law must be sharply focused so as to assure that the beneficiary cannot accept the tax reduction without changing his activities. Sellers, buyers, or trans porters of wood residue could be made eligible for appropriately designed tax treatment.

D.2.2 Investment Incentives

An investment credit provision could be established for the target industry (i.e., mills, wood residue transporters, even some categories of wood residue buyers, such as those who convert from oil to wood fired burners). This tax credit would permit the deduction from taxable income of a portion (or even all) of the capital investment made by a business; such a deduction has the effect of encouraging markets for wood residue. A variation of this strategy, most appropriate for low income target industries, would permit the investment cost to be credited against the tax actually due. Still another variation would permit faster depreciation of capital equipment purchased to dispose of wood residue in desirable ways, thereby reducing the tax burden experienced by the target business during the life of the new equipment (Pechman et al., 1977).

Certain user tax rates could be reduced as a means of reducing the cost of operating within a particular market for wood residue. For example, a reduction in the vehicle-weight-per-mile tax on truck transport in Montana might improve the economic feasibility of moving wood residue to distant markets by truck. User tax reductions are easier to target effectively against particular impediments to market viability, such as the cost of truck transportation for wood residue. The typical disadvantage of reducing user taxes is that the revenue from such taxes is usually earmarked for the maintenance of what is being used (e.g., State highways in Montana). The reduced revenue must be made up for from other sources.

D.2.4 Product Tax Reductions

It might be possible to reduce the tax rates paid on products made from wood residue as a means of increasing demand for them. By lowering the price of these products, such a tax reduction might encourage the demand for them to rise, thereby expanding the market. For example, it might be possible to exempt wood products from some or all State or local sales or excise taxes. Another possibility is to reduce the per gallon tax on fuels blended with alcohols made from wood waste.

D.2.5 Choosing Between Spending and Taxing Incentives

In terms of cost to the government involved, little choice exists between a tax reduction and a program expenditure of identical dollar size. For this reason, the term "tax expenditure" has come into common use for describing selective tax reductions (Pechman, 1978). However, the pattern of incentives established by the two can differ. For example, the literature points out that a tax reduction can often be of greater benefit to larger, more well-to-do companies than to smaller, struggling ones for several reasons. Larger companies often have access to greater expertise in interpreting the tax laws. They frequently are more diversified and therefore may have more opportunities to take advantage of a given incentive provision. They often are better able to plan their activities on a multiyear basis, thereby taking more complete advantage of those possible incentives that involve advance planning.

A second difference between program expenditures and tax reductions is that tax reductions are less visible to the general public than are program expenditures. If gaining sufficient political support for an incentive program is likely to be a problem, a tax reduction may be easier to enact than a program expenditure, even if they result in exactly the same dollar drain on the public treasury.

D.2.6 A Summary of the Incentive Strategies

Two tables summarize the possible strategies available to the State of Montana. Table D-1 summarizes the probable effects of the various strategies on the incentives that operate in the forestry industry. These effects are summarized in terms of the extent of a given incentive:

- o Improves expected economic rewards to the target industry
- o Reduces risks to the industry in shifting away from tepee burners
- o Reduces the marketplace uncertainty inherent in such a shift
- o Improves the industry's access to capital.

Table D-2 summarizes some of the probable policy implications of each incentive strategy in terms of four criteria. Included are summary evaluations of each strategy's effectiveness in:

TABLE D-1

PROBABLE EFFECTS OF VARIOUS STRATEGIES ON INCENTIVES IN THE FORESTRY INDUSTRY

Incentive-Creating Strategy	Probable Impact on Investment Decision Process: Improves Expected Reward to Industry	Reduces Project Risks to Industry	Reduces Marketplace Uncertainty	Improves Access to Capital
Front-end incentives				
Investment tax credit	P	S	--	S
Capital cost expensing	P	S	--	S
Accelerated depreciation	P	S	--	S
Construction grant	P	S	--	P
Direct loan	--	--	--	--
Purchase agreements	P	--	--	P
Loan guarantee	--	--	--	--
Production incentives				
Tax credit tied to production levels	P	S	--	--
Price guarantee	--	--	P	--
Sales tax reduction	--	--	P	--
Property tax reduction	--	--	--	--
Other incentives				
Sponsoring R&D	--	--	P	--
Market information dissemination	--	--	P	--

Legend: P = Primary impact
S = Secondary impact

TABLE D-2

PROBABLE POLICY IMPLICATIONS OF INCENTIVE CREATING STRATEGIES IN THE FORESTRY INDUSTRY

Incentive-Creating Strategy	Requires Least Governmental Involvement	Promotes Greatest Economic Efficiency	Offers Greatest Public Participation	Implies Least Uncertain Financial Exposure to Government
Front-end incentives				
Investment tax credit	H	M	M	M
Capital cost expensing	H	M	M	M
Accelerated depreciation	H	M	M	M
Construction grant	L	L	H	H
Direct loan	L	L	H	M
Purchase agreements	L	L	H	M
Loan guarantee	M	M	M	M
Production incentives				
Tax credit tied to production levels	H	M	M	M
Price guarantee	L	L	H	L
Sales tax reduction	H	M	M	M
Property tax reduction	H	M	M	M
Other incentives				
Sponsoring R&D	L	H	L	H
Market information dissemination	M	M	H	H

Legend: H = High effectiveness
M = Medium effectiveness
L = Low effectiveness

- Requiring the least governmental involvement
- Promoting the greatest economic efficiency
- Offering the greatest breadth of public participation
- Implying the least uncertain governmental financial exposure

The conclusions represented in these tables are based solely on the literature and are highly preliminary.

D.3 POSSIBLE INCENTIVES ASSOCIATED WITH REGULATORY ACTIVITIES

The principal regulatory tool available to the State of Montana to reduce tepee burner emissions is Section 16-2.14(1)-S14030 of the Air Quality Rules established under the Clean Air Act of Montana (revisions effective July 1, 1979). This section governs wood-waste burners, and its applicable provisions are quoted below:

> 16-2.14(1)-S14030 WOOD-WASTE BURNERS
>
> (1) Construction, reconstruction, or substantial alteration of wood-waste burners is prohibited unless the requirements of the permit rule, ARM 16-2.14(1)-S-1415 have been met.
>
> (2) No person shall cause or authorize to be discharged into the outdoor atmosphere from any wood-waste burner any emissions which exhibit an opacity of twenty percent (20%) or greater averaged over six (6) consecutive minutes.

Remedies available under the Clean Air Act of Montana are contained in Part 4 of the Act. Relevant portions of this part include:

Enforcement, Appeal, and Penalities

75-2-401. Enforcement

(1) When the department believes that a violation of this chapter or a rule made under it has occurred, it may cause written notice to be served personally or by registered or certified mail on the alleged violator or his agent. The notice shall specify the provision of this chapter or rule alleged to be violated and the facts alleged to constitute a violation and may include an order to take necessary corrective action within a reasonable period of time stated in the order. The order becomes final unless, within 30 days after the notice is received, the person named requests in writing a hearing before the board. On receipt of the request, the board shall schedule a hearing.

(2) If, after a hearing held under subsection (1) of this section, the board finds that violations have occurred, if shall either affirm or modify an order previously issued or issue an appropriate order for the prevention, abatement, or control of the emissions involved or for the taking of other corrective action it considers appropriate. An order issued as part of a notice or after a hearing may prescribe the date by which the violation shall cease and prescribe time limits for particular action in preventing, abating, or controlling the emissions. If, after hearing on an order contained in a notice, the board finds that no violation is occurring, it shall rescind the order.

(3) Instead of issuing the order provided for in subsection (1), the department may either: (a) require that the alleged violators appear before the board for a hearing at a time and place specified in the notice and answer the charges complained of; or (b) initiate action under 75-2-412 or 75-2-413.

(4) This chapter does not prevent the board or document from making efforts to obtain voluntary compliance through warning, conference, or any other appropriate means.

(5) In connection with a hearing held under this section, the board may and on application by a party shall compel the attendance of witnesses and the production of evidence on behalf of the parties.

If the alleged violator believes he has been unfairly judged, he may seek legal relief at the conclusion of this process. The Act specifies the procedures under which such actions may occur:

> 75-2-411. Judicial review
>
> (1) A person aggrieved by an order of the board or local control authority may apply for rehearing upon one or more of the following grounds and upon no other grounds:
>
> (a) the board or local control authority acted without or in excess of its powers;
> (b) the order was procured by fraud;
> (c) the order is contrary to the evidence;
> (d) the applicant has discovered new evidence, material to him, which he could not with reasonable diligence have discovered and produced at the hearing; or
> (e) competent evidence was excluded to the prejudice of the applicant.
>
> (2) The petition must be in such form and filed in such time as the board shall prescribe.
>
> (3) (a) Within 30 days after the application for rehearing is denied or, if the application is granted, within 30 days after the decision on the rehearing, a party aggrieved thereby may appeal to the district court of the judicial district of the State which is the situs of property affected by the order.
>
> (b) The appeal shall be taken by serving a written notice of appeal upon the chairman of the board, which service shall be made by the delivery of a copy of the notice to the chairman and by filing the original with the clerk of the court to which the appeal is taken. Immediately after service upon the board, the board shall certify to the district court the entire record and proceedings, including all testimony and evidence taken by the board. Immediately upon receiving the certified record, the district court shall fix a day for filing of briefs and hearing arguments on the cause and shall cause a notice of the same to be served upon the board and the appellant.
>
> (c) The court shall hear and decide the cause upon the record of the board. The court shall determine whether or not the board regularly pursued its authority, whether or not the findings of the board were supported by substantial competent

> evidence, and whether or not the board made errors of law prejudicial to the appellant.
>
> (4) Either the board or the person aggrieved may appeal from the decision of the district court to the supreme court. The proceedings before the supreme court shall be limited to a review of the record of the hearing before the board and of the district court's review of that record.

D.3.1 Incentives Resulting From Regulatory Approaches

These provisions express a common regulatory approach to the problem of bringing about changes in public behavior--that of proscribing specific actions and bringing legal action against alleged offenders. Although this approach cannot be avoided, the incentives that such an approach engenders among those regulated should be recognized. The literature argues that this approach gives the regulated industry incentives to (1) avoid being detected violating environmental standards, rather than searching for ways to meet them; (2) if detected, challenge the action of the regulatory body in court; and (3) appeal decisions made against it at each level of judicial review (Schultz, 1977).

The judicial review procedures outlined above are highly desirable for assuring due process of law. However, they may also promote a time-consuming legal struggle against the desired changes in industry behavior as well as providing no positive incentive to adopt nonpolluting behavior. For these reasons, direct regulation alone should be viewed as a last resort. It is most effective when used in conjunction with positive incentives in a "carrot and stick" fashion.

APPENDIX E

A LIST OF REFERENCES ON WOOD RESIDUE TOPICS

Adams, T.C. and R.C. Smith. 1976. "Review of the Logging Residue Problem and Its Reduction Through Marketing Practices." USDA-Forest Service, General Technical Report, PNW-48. Pacific Northwest Forest and Range Experiment Station.

Adkinson, V.J. June 1978. "The Economic and Social Effect of Hogged Fuel on the Environment of Lane County, Oregon." Forest Products for Proceedings from the Research Society Annual Meeting. Pollution Abatement and Control Committee.

Allison, F.E. and M.S. Anderson. November 1951. "The Use of Sawdust for Mulches and Soil Improvement." USDA Circular No. 891, Washington, DC.

Anderson, A.B., A. Wong, and King-Tsuen Wu. January 1974. "Utilization of White-fir Bark in Particleboard." Forest Prod. J. 24(1):51-54.

_____. July 1974. "Utilization of White-fir Bark and Its Extract in Particleboard." Forest Prod. J. 24(7):40-45.

_____. August 1974. "Utilization of Ponderosa Pine Bark and Its Extract in Particleboard." Forest Prod. J. 24(8):48-53.

Arola, R.A. 1975. "Logging Residue; Fuel, Fiber or Both." ASAE Trans. 18(6):1027-31.

_____. November 1976. "Wood Fuel -- How Do They Stack Up?" Proceedings from the Energy and the Wood Products Industry, FPRS #P-76-14, Atlanta, GA.

Atherton, G.H. and S.E. Corder. February 1969. "A Study of Wood and Bark Residue Disposal in the Forest Products Industries." Preliminary report to 55th Legislative Assembly.

Baker, A.J. and E.H. Clarke. 1976. "Wood Residue As An Energy Source -- Potential and Problems." Proceedings from the Rocky Mountain Forest Industry Conference.

Baxter, H.O. (Compiler). "Summary of Research on Sawdust and Bark for Agricultural Uses." Co-operative Extension Service. College of Agriculture, University of Georgia, Athens, GA.

Bergmeir, R.E. and A.C. Bjergo. April 1972. "Ground Bark for Bedding, the First Phase of the Bitterroot Recycling Project." Proceedings from the 27th Annual Northwest Wood Products Clinic, Spokane, WA.

Bergvall, J.A., D.C. Bullington, L. Gee, January 1979. "Wood Waste for Energy Study -- Final Literature Review." Prepared for State of Washington House of Representatives Committee on Natural Resources.

Bergvall, J.A., L. Gee, and W. Koss. January 1979. "Wood Waste for Energy Study--Executive Summary." Prepared for State of Washington House of Representatives, Committee on Natural Resources.

Blackman, T. (associate editor). February 1978. "Crude Oil from Wood Chips? Test Plant Shows It's Possible." Forest Industries 105(2):50-1.

Boubel, R.W., M. Northcraft, A. Van Vliet, and M. Popovich. 1958. "Wood Waste Disposal and Utilization." Bulletin No. 39, U.S. Public Health Service Commission, Air Pollution Demonstration Project Grant A-57-941.

Boubel, R.W. 1965. "Wood Residue Incineration in Tepee Burners." Engineering Experiment Station, Oregon State University, Circular No. 34.

Buongiorno, J. and R.A. Oliveira. 1977. "Growth of the Particleboard Share of Production of Wood-Based Panels in Industrialized Countries." Canadian Journal of Forest Research 7(2):383-391.

Camran Corporation. November 1974. "A Proposal for Resource Recovery of Logging Wastes in Region X Area."

Carpenter, E.M. 1977. "Secondary Wood Residue Production, Use and Potential in the Twin City Area." USDA-Forest Service Research Paper NC-144. North Central Forest Experiment Station.

Christensen, G.W. 1975. "Wood Residue Sources, Uses and Trends." Proceedings from Wood Residue As An Energy Source, FPRS No. P-75-13, p. 39-41.

Clarke, E.H. and J.W. Henley. "Unused Mill Residuals May All Serve as Fuel." Forest Industries 105(2):54-5.

Corder, S.E., G.H. Atherton, P.E. Hyde, and R.W. Bonlie. March 1970. "Wood and Bark Residue Disposal in Wigwam Burners." Forest Research Laboratory. Oregon State University, Bulletin 11.

Corder, S.A. February 1974. "Wood-Bark Residue is Source of Plant Energy." Forest Industries 101(2):72-3.

Currier, R.A. November 1971. "Physical Considerations." In Converting Bark into Opportunities. Compiled by Antone C. Van Vliet. Proceedings of conference held March 8-9, Oregon State University Forest Products Department.

_____. April 1972. "An Assessment of Current Bark Utilization Opportunities." Proceedings from the 27th Annual Northwest Wood Products Clinic, Spokane, WA.

Currier, R.A., and M.L. Laver. "Utilization of Bark Waste." Department of Forest Products, Oregon State University, Terminal Progress Report, EPA Grant No. R-EP 00276-04.

Currier, R.A. and W.F. Lehmann. November 1971. "Bark As An Ingredient in Molded Items, Particleboards, Adhesives and Other Products." In Converting Bark into Opportunities. Compiled by Antone C. Van Vliet. Proceedings of conference held March 8-9. Oregon State University Forest Products Department.

Davie, B.F. and B.F. Duncombe. Public Finance, Holt, Rhinehart and Winston, Inc., New York, 1972.

Dell, J. (editor). "A Status Report on Potential Use of Forest Residues for Energy Production." Prepared by Aviation and Fire Management.

Dickerhoof, H.E. "Insulation Board, Hardboard and Particleboard Industries: Past Accomplishments, Future Problems and Opportunities." Forest Products Journal 25(41):11-16.

_____. "Particleboard Production, Markets and Raw Materials in the U.S." Forest Products Journal 26(10):16-20.

_____. February 1977. "Particleboard Production, Markets and Raw Material Use in the Western U.S. as surveyed by U.S. Department of Agriculture." Plywood and Panel.

Ellis, T.H. October 1975. "Should Wood Be a Source of Commercial Power?" Forest Products Journal 25(10):13-16. Forest Products Laboratory, Madison, WI.

_____. 1975. "The Role of Wood Residue in the National Energy Picture." Proceedings from Wood Residue as an Energy Source, FPRS No. P-75-13, p. 17-20.

Erickson, J.R. "Harvesting of Forest Residues." AIChE Symposium Series 71(146):27-29.

Evans, R.S. July 1973. "Hogged Wood and Bark in British Columbia Landfills." Department of the Environment -- Canadian Forest Service (Information Report) UP-X-118.

Fahey, T.D. and E. Starostovic. April 1979. "Changing Resource Quality: Impact on the Forest Products and Construction Industries." Forest Products Journal 29(4):39-43.

Fuller, W.H. 1966. "New Organic Pelleted Compost." Compost Science, Autumn-Winter, p. 30.

Grantham, J.B. 1974. "Status of Timber Utilization on the Pacific Coast." USDA-Forest Service, General Technical Report PNW-29. Pacific Northwest Forest and Range Experiment Station. Portland, OR.

_____. 1976. "Energy Potential of Forest Residue." USDA-Forest Service, Proceedings from the Northwest Forest Fire Council Annual Meeting, pp. 76-79.

_____. February 1978. "Wood's Future Seems Directed to Energy Ahead of Chemicals." Forest Industries 105(2):52-3.

Grantham, J.B. and T.H. Ellis. September 1974. "Potentials of Wood for Producing Energy." J. Forestry 72(9):552-556. Forest Products Laboratory, Madison, WI.

Grantham, J.B., E.M. Estep, J.M. Pierovich, H. Tarkow, and T.C. Adams. 1974. "Energy and Raw Materials Potential of Wood Residue in the Pacific Coast States. A Summary of a Preliminary Feasibility Investigation." USDA-Forest Service, General Technical Report PNW-18. Pacific Northwest Forest and Range Experiment Station, Portland, OR.

Halak, B. August 1977. "COFI Backing Gasification Project." British Columbia Lumberman, pp. 44-48.

Haley, T.I. May 1971. "Wood Waste Fuel-Economics-Supply-Prospects-Preparation and Handling." 1971. Technical Program. Hog-fuel Boiler Emission Control Workshop, Olympia, WA.

Hail, E.H. November 1976. "Comparison of Fossil and Wood Fuels." Proceedings from the Energy and the Wood Products Industry, FPRS No. P-76-14, pp. 141-45. Atlanta, GA.

Harkin, J.M. November 1969. "Uses for Sawdust, Shavings and Waste Chips." USDA-Forest Service, Research Note FPL-0208. Forest Products Laboratory, Madison, WI.

Harkin, J.M. and J.W. Rowe. October 1969. "Bark and Its Possible Uses." USDA-Forest Service, Research Note FPL-091. Forest Products Laboratory, Madison, WI.

Hodam, R. February 1978. "Economical Energy Conversion Promised by Wood Gasification." Forest Industries 105(2):56.

Hoff, E.B. November 1976. "Handling of Forest Products Fuel." Proceedings from the Energy and the Wood Products Industry, FPRS No. P-76-14, pp. 46-48. Atlanta, GA.

Hokanson, A.E. and R.M. Rowell. 1977. "Methanol from Wood Waste: A Technical and Economic Study." USDA-Forest Service, General Technical Report FPL-12, Forest Products Laboratory, Madison, WI.

Host, J.R. and D.P. Lowery. February 1970. "Potentialities for Using Bark to Generate Steam Power in Western Montana." Forest Products Journal 20(2):35-6.

____. 1970. "Portable Debarking and Chipping Machines Can Improve Forestry Practices." USDA-Forest Service, Research Note INT-112. Intermountain Forest and Range Experiment Station, Ogden, UT.

Howlett, K. and A. Gamache. May 1977. "Silvicultural Biomass Farms. Volume VI: Forest and Mill Residues as Potential Sources of Biomass." Prepared by Mitre Corp., METREK Division. For ERDA (Division of Solar Energy), Contract No. EX-76-C-01-2081.

Hoyt, G.W. July 1975. "Air Curtain Destructors." Waste Age, pp. 37-43.

Inman, R.E. 1977. "Silvicultural Biomass Farms. Volume I: Summary." METREK Division, Mitre Technical Report No. 7347 - Vol. I. Sponsor: ERDA. No. E (49-18)-2081. Project No. 2170, Department: W52.

Interim Task Force -- Forest Slash Utilization. October 1977. "Minutes of Alternative Uses Subcommittee." State of Oregon.

Johnson, R.C. July 1975. "Some Aspects of Wood Waste Preparation for Use as Fuel." Tappi 58(7):102-106.

Junge, D.C. November 1977. "Outline for Presentation to the Task Force on Forest Slash Utilization." Portland, OR.

Kalish, J. August 1977. "Pros and Cons of TMP Discussed at Mechanical Pulping Meeting." Pulp and Paper, pp. 107-111.

Knapp, H.J. November 1976. "Potential of Industrial Wood Residue for Energy." Proceedings: Energy and the Wood Products Industry. FPRS No. P-76-14, pp. 105-107. Atlanta, GA.

Knudson, R.M., R.M.T. Stout and D.E. Rogerson. September 1978. "Plywood Glue Extender From Particleboard Sander Dust." Forest Products Journal, p. 44.

Lehmann, W.F. and H.E. Wahlgreen. 1978. "Status and Prospects of Residue Utilization in Board Product Manufacture in the U.S. and Canada." Forest Products Journal 28(7):24-29.

Lempicki, E.A., G.H. Pierson, and G. Niskala. October 1978. "Wood Residue Utilization Program in New Jersey." Forest Products Journal 28(10):83-85.

Lowery, D.P., J.P. Krier, and J.R. Host. June 1977. "Bark Residues in Western Montana." USDA-Forest Service, Research Note INT-140. Intermountain Forest and Range Experiment Station, Ogden, UT.

Maloney, T.M. August 1973. "Bark Boards from Four West Coast Softwood Species." 1973. Forest Products Journal 23(8):30-38.

Mason, R.L. 1975. "Value of Residues for Fuel Use Versus Value for Products." Proceedings from Wood Residue as an Energy Source, FPRS No. P-75-8, pp. 27-29.

Mater, Jean. January 1969. "How to Turn Bark into Dollars." 1969. Wood and Wood Products 74(1).

_____. August 1971. "Utilization of Bark in Highway Landscaping." Forest Products Journal 21(8):14-20.

Maugh II, T.H. November 1972. "Fuel from Wastes: A Minor Energy Source." Science 178(4061):599-602.

Moore, W.E. September 1975. "Mill Residues; What Are They Really Worth?" Proceedings from Wood Residue As An Energy Source. FPRS No. P75-13, pp. 21-26. Denver, CO.

Oregon State University Extension Service. July 1977. "Manufacturing Densified Wood and Bark Fuels." Special Report 490.

Orr, A. May 1974. "Generation of Energy from Wood Waste." In Fiber Conservation and Utilization. Proceedings of Pulp and Paper Seminar, Chicago, IL.

Pease, D.A. May 1972. "Plywood Scrap Converted Into Compressed Firelogs." World Wood 13(5):6-7.

Pechman, J.A., and B.A. Okner. 1974. Who Bears the Tax Burden? The Brookings Institution, Washington, DC.

Pierovich, J.M. and R.C. Smith. 1973. "Choosing Forest Residues Management Alternatives." USDA-Forest Service, General Technical Report PNW-7. Pacific Northwest Forest and Experiment Station.

Reed, T.B. and R.M. Lerner. December 1973. "Methanol: A Versatile Fuel for Immediate Use." Science 182(4119):1299-1304.

Ruderman, F.K. 1978. "Production, Prices, Employment Trade in NW Forest Industries, Second Quarter 1978." USDA-Forest Service, Pacific Northwest Forest and Range Experiment Station.

Schaffer, E.L. 1976. "Forest Residue Into Structural Flakeboard: A Forest Service National Program." Transactions of ASAE 19(3):417-21, 427.

Schultze, Charles L., 1977. The Public Use Of Private Interest. The Brookings Institution, Washington, DC.

Siegel, G.R. 1975. "Wood Residue As a Fuel in the Commercial Production of Electricity." Proceedings from Wood Residue as an Energy Source, FPRS No. P-75-13, pp. 94-97. Denver, CO. September 3-5.

Simon, J. November 1976. "Dying Fiber with Wood Waste." Proceedings from the Energy and the Wood Products Industry, FPRS No. P-76-14, pp. 101-102. Atlanta, GA.

Snowden, W.D. (Alsid, Snowden & Associates). "Alternate Fuel Evaluation." Washington Corrections Center. State of Washington, Department of General Administration, Division of Engineering and Architecture, Contract 76-792A.

Winstead, T.E. 1974. "Developments in Pulping Woodwastes." In Fiber Conservation and Utilization. Proceedings of May Pulp and Paper Seminar. Chicago, IL. Editors: P.D. VanDerveer and K.E. Lowe.

Wisherd, K.D. and J.B. Wilson. February 1979. "Bark as a Supplement to Wood Furnish for Particleboard." Forest Products Journal 29(2):35-39.

Wolf, C.H. and J.L. Wartluft. 1969. "Hardwood Bark...From Nuisance to Nest Egg." Northern Loger 18(2):20-1, 66-68.

Young, H.E. 1975. "Utilization of Forest Residues - A Segment of the Complete Tree Concept." Proceedings from the Society of American Foresters National Convention, Washington, pp. 479-484.

Youngs, R. 1972. "Residue Utilization Research at Forest Products Laboratory." Close Timber Utilization Committee Report. USDA-Forest Service, pp. 45-49.

Zoch, L.L., E.J. Springer, and G.J. Hajny. 1976. "Storage of Aspen Whole-Tree Chips Under Laboratory Conditions." USDA-Forest Service. Research Paper FPL 288. Forest Products Laboratory, Madison, WI.

_____. Anonymous - January 1971. "Bark Marketing: The Potential." Forest Farmer (official publication of Forest Farmer Association, Atlanta, GA).

_____. Anonymous - July 1977. "Plant Burns Its Trash for Heating." Pulp and Paper, p. 101.

_____. Anonymous - January 1978. "Synthetic Gas From Forest Residue Studied." Forest Industries, p. 70.